SUGGEST TO REPLACE WITH EQUIVALENT GRAPHITE SPAR TAPERED FROM 2 1/2" O.D. TO 1 3/4"

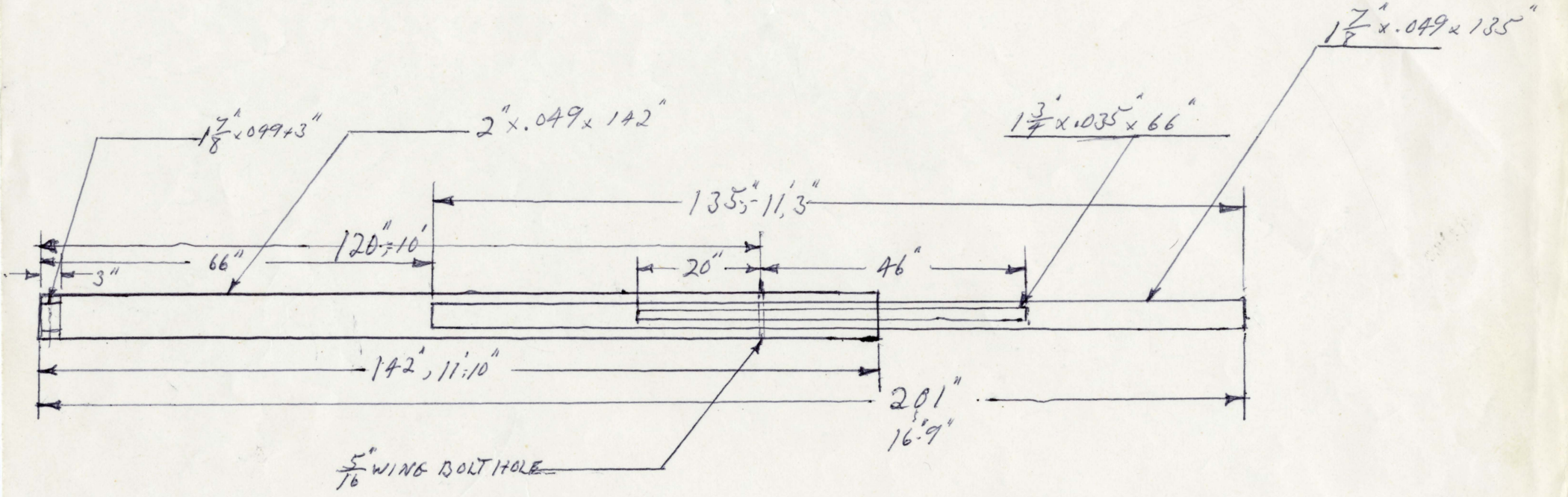
HANG GLIDER SENSOR 510 LEADING EDGE

(2) REQUIRED

SCALE 1/2" = 1'

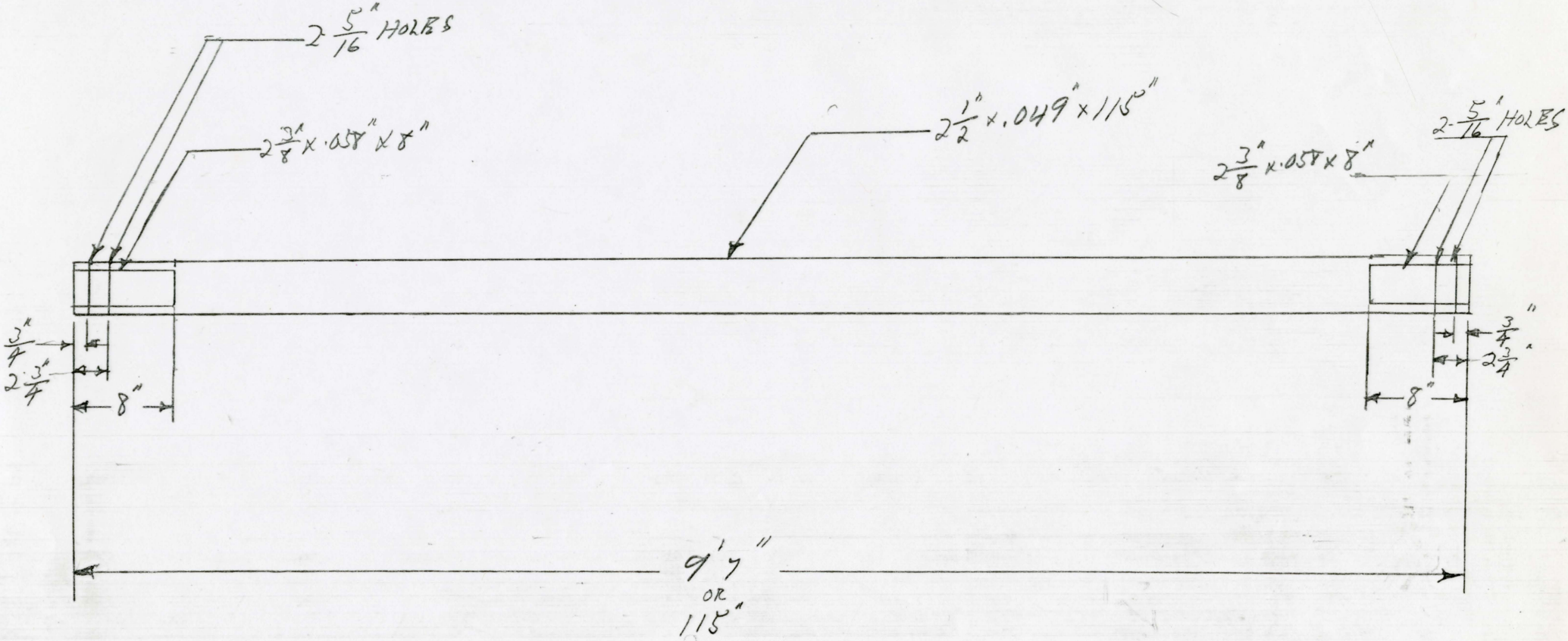
WT. = 9.2 lbs/L.E.

OR 18.4 lbs FOR (2)



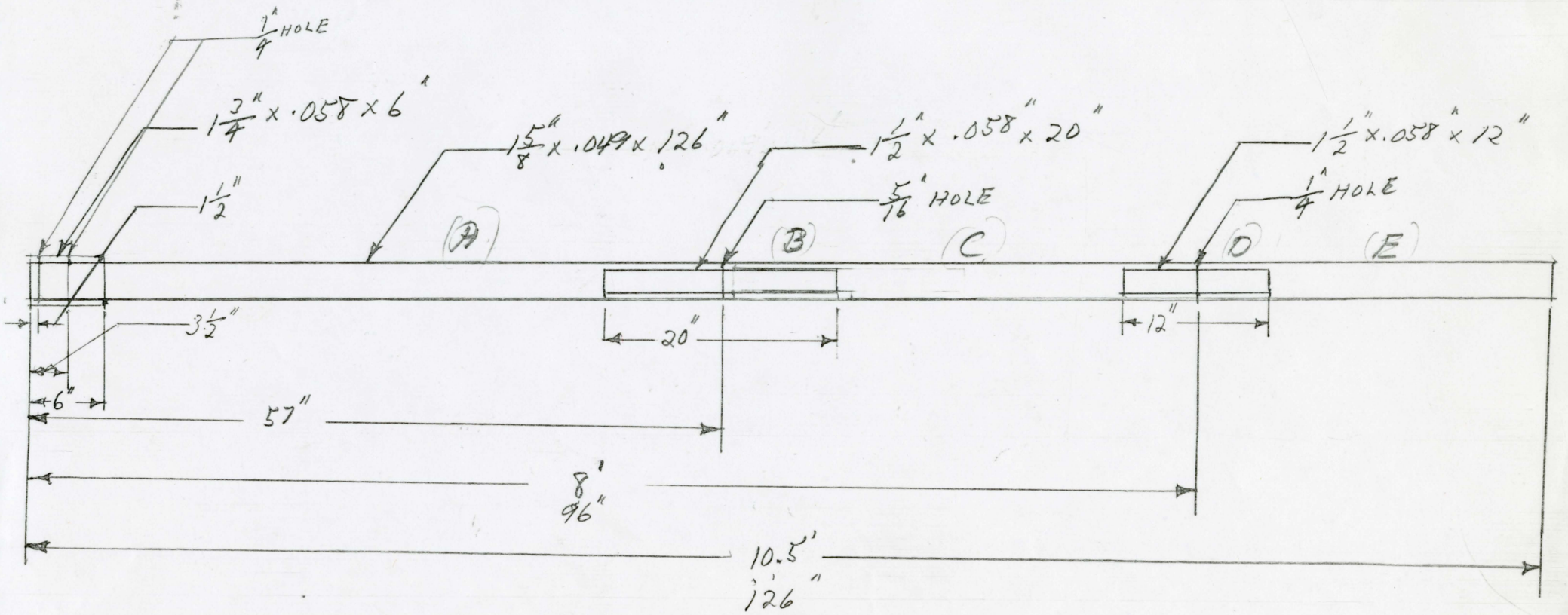
SENSOR-510-CROSSTUBE

2- REQUIRED



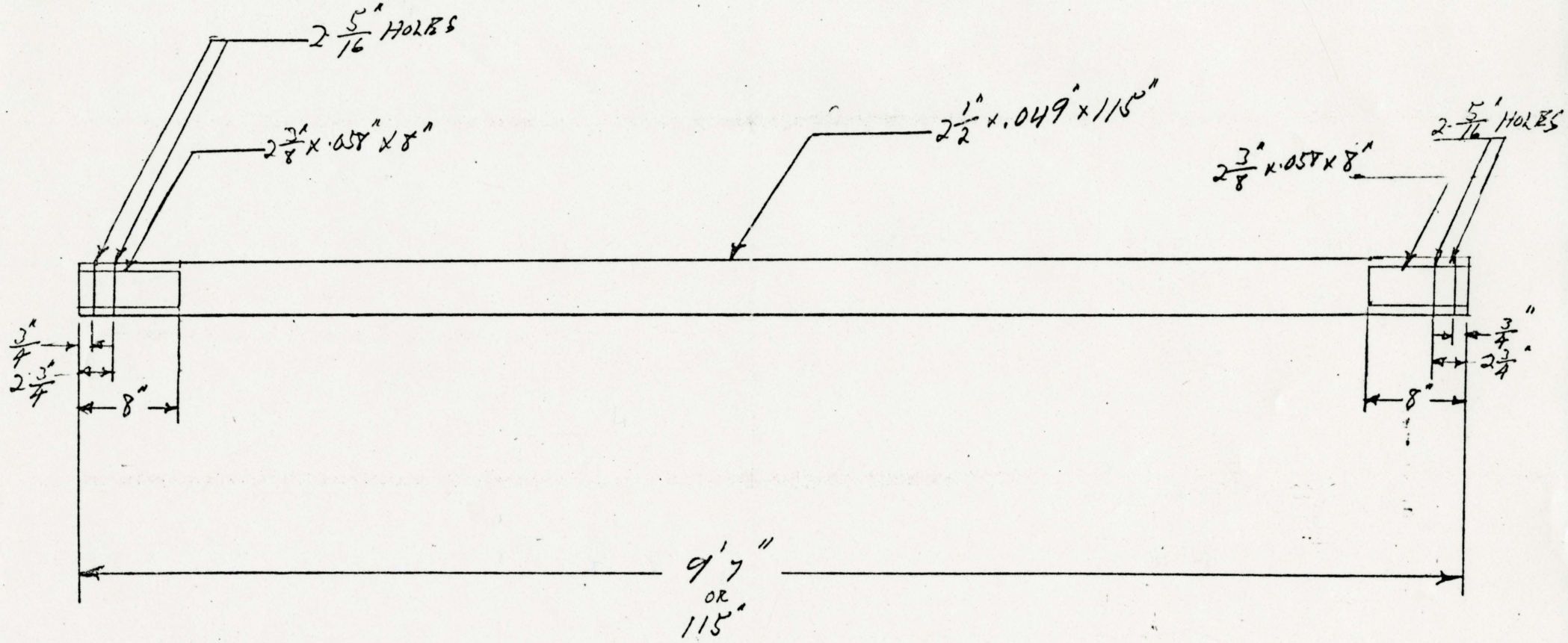
SENSOR 510 KEEL

1-REQUIRED



SENSOR-510 CROSSTUBE

2- REQUIRED



SUGGEST TO REPLACE WITH EQUIVALENT GRAPHITE SPAR TAPERED FROM $2\frac{1}{2}$" OD TO $1\frac{3}{4}$"

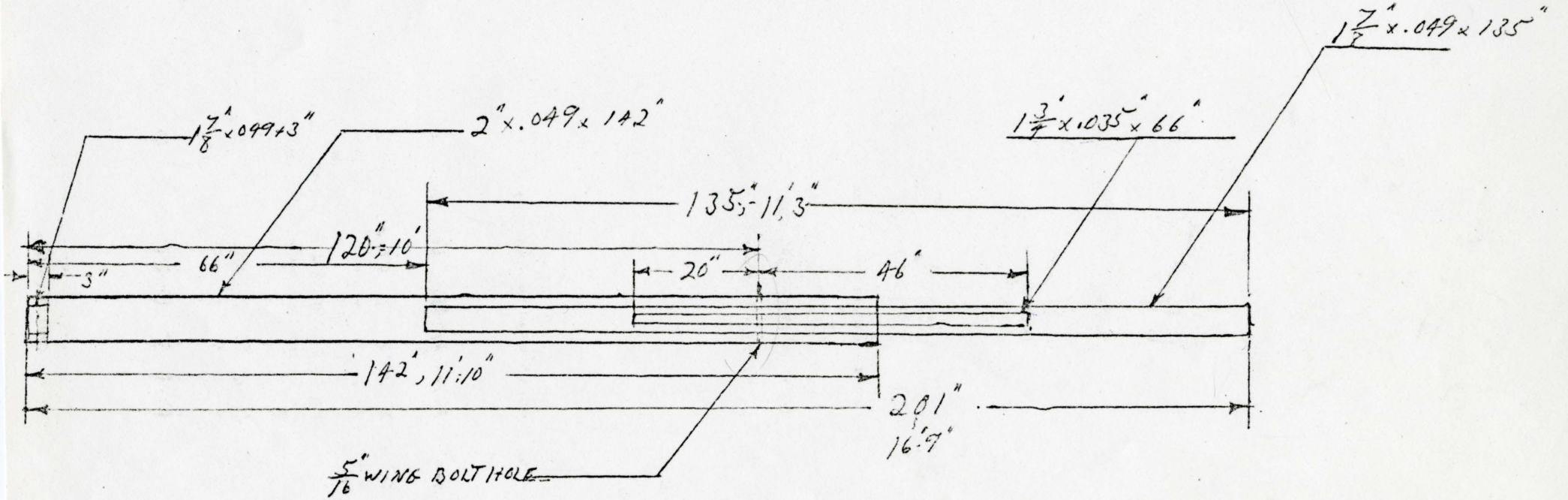
HANG GLIDER SENSOR 510 LEADING EDGE

(2) REQUIRED

SCALE $\frac{1}{2}$" = 1'

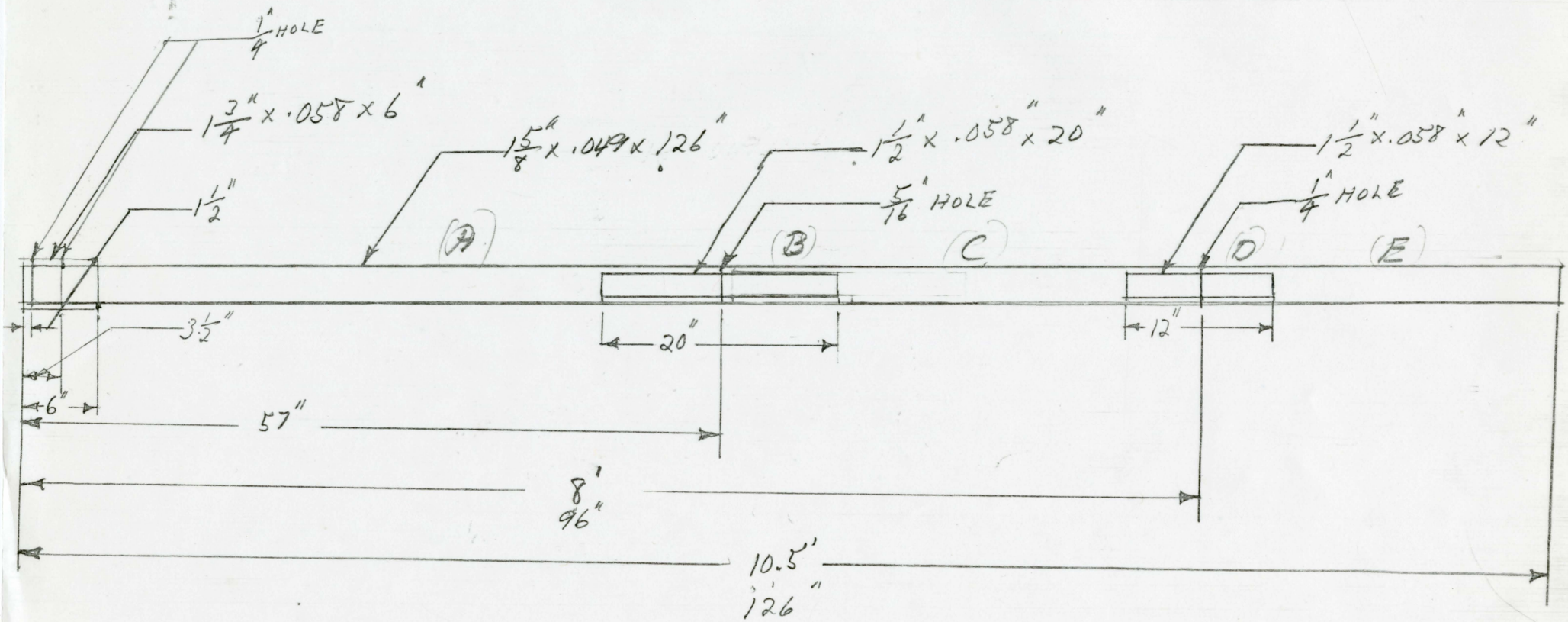
WT. = 9.2 lbs/L.E.

OR 18.4 lbs FOR (2)



SENSOR 510 KEEL

1-REQUIRED



BILL BROOD

TEST 16 May 84

AL		#1 GRAPHITE	
WT.	DEFLECTION	WT	DEFLECTION
0 lb	70	0	70
10 "	69 1/4	10"	69 1/2
30 "	67 3/4	30	68 1/4
50 "	66 1/4	50	67 1/4
70 "	65	70	66
90 "	63 3/4	90	65
110 "	62 1/4	110	64
130 "	61	130	63
150 "	59 3/4	150	62
160 "	59	176	61
170 "	58 1/2	190	60 1/2
180 "	57 3/4	198	60
190 "	57 1/4	200	59 1/2
200 "	56 1/2	216	59
210 "	55 3/4		

WT. OF AL TUBE 9.55 lbs

WT #1 TUBE 5.75 lbs.

NOTE

I have been working for the past two years with a graduate student, Craig Douglas, on graphite designed tubing for my Sensor 210 D-165, with Bob Trampenau's permission of course. We had about $ 3000 worth of graphite tubing. It was 2" and 1 1/2" X .050" wall thickness, 6' lengths, and spun in different weaves from 5° -90°, which governs the stiffness or flexibility of the tubes. With Bob's reccomendation we used the 2" on the leading edges and 1 1/2" on the keel and cross tube. We did bending tests on all the different angles the tubes were spun at. (Results are enclosed with this material). We found that the 25° graphite was about the same stiffness as the Aluminum. We used 25° on the forward keel, 5° on aft keel, 25° on the crossmember and 30° on the 2" leading edges. The tubes were sleeved and bushed wherever there was a bolt or splice with stainless steel bushing or anodized aluminum sleeves. The tubes were joined by sleeves with 2 ton 1/2 hour epoxy glue.

The College of Engineering has allowed me to work on this project for the past year, during working hours. Since they paid for all the tubing, I furnished the money for all the new hardware (sail and all anodized sleeves and other parts cost me $550) First, I replaced the keel with graphite on my glider and flew it, next the crossmember, and finally the leading edges. After all the tubes were replaced I bought a new white sail, fitting it with all new parts. I then put all the aluminum back onto the old glider. It was a step by step operation. The weight reduction was not as much as I expected because the leading edges were 1 5/8" and ~~about~~ 1 1/2" replaced by 2" graphite. Tube for tube it is just about 40% lighter and twice as strong. In tension tests the bolts pulled right through the Aluminum sleeves that were epoxied onto the graphite. The glider at the start weighed 51 pounds, while after conversion it weighed only 45 pounds. The sail weight was 10 pounds, the control bar, king post, deflexor, define tips and battens about 10 pounds. I have ordered a control bar, king post and defined tips in graphite also, and they should reduce the weight by about 5 pounds more. The College of Engineering is also paying for more graphite tubing, 1 7/8" and 1 5/8" for a deflexorless, Sensor 510.

ENCLOSER 1

18 Jan. 1980

TUBING COMPARISON

Keel-aluminum	Weight--- 1983 grams or 4.37 pounds
Keel-graphite	Weight---1180 grams or 2.60 pounds
Cross tube-aluminum	Weight--- 1297 grams or 2.86 pounds
Cross tube-graphite	Weight--- 877 grams or 1.93 pounds

Leading edge

Aluminum (1 5/8"& 1 1/2")	Weight--- 2782 grams or 6.13 pounds
Graphite (2")	Weight--- 2603 grams or 5.73 pounds

GRAPHITE TESTS

1 1/2" X .050"-.006 ±5°

Weight	Deflection
0	1.551
4 lbs-6 oz.	1.560
24 lbs-6 oz.	1.604
44 lbs	1.660
64 lbs	1.717
84 lbs	1.776
104 lbs	1.810
124 lbs-6 oz.	1.858

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^3 avg.\ t}$$

$$E = 14.31 \times 10^6$$

1 1/2" X .050"-.004 ±45°

Weight	Deflection
0	1.571
4 lbs-6 oz.	1.626
24 lbs	1.862
44 lbs	2.128
64 lbs	2.370
84 lbs	2.653
104 lbs	2.964

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^3 avg\ t}$$

$$E = 2.7 \times 10^6$$

1 1/2" X .050"-.003 ± 25°

Weight	Deflection
0	1.540
4 lbs 6 oz.	1.570
24 lbs 6 oz.	1.630
44 lbs 6 oz.	1.724
64 lbs 6 oz.	1.800
84 lbs 6 oz.	1.876
104 lbs 6 oz.	1.975

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^2 avg\ t}$$

$$E = 8.52 \times 10^6$$

ALUMINUM TESTS

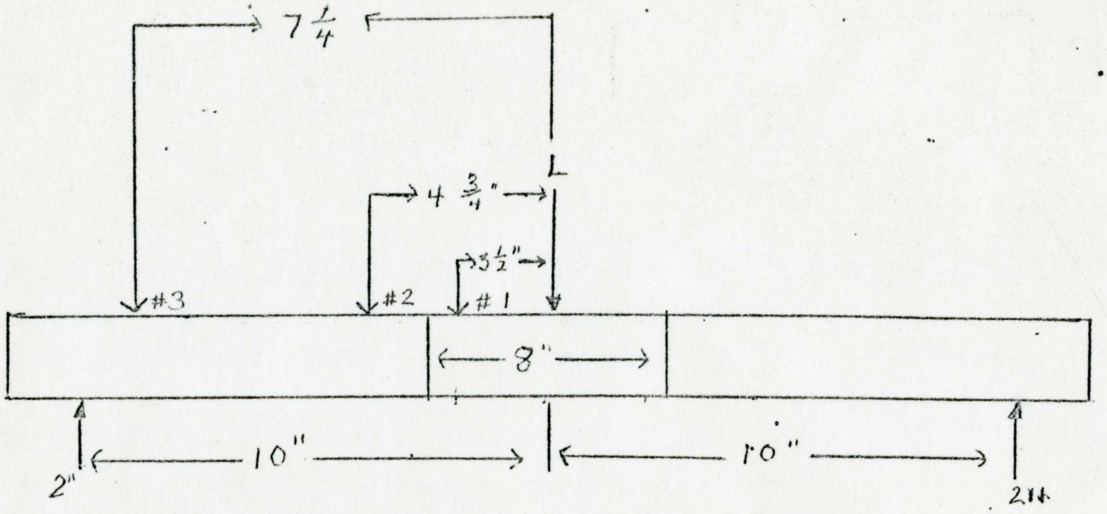
1 1/2" X .040"

Weight	Deflection
0	1.573
4 lbs 6 oz.	1.610
24 lbs 6 oz.	1.690
44 lbs	1.768
64 lbs	1.834
84 lbs	1.927
104 lbs	1.987

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^4 avg\ t}$$

$$E = 8.95 \times 10^6$$

Bending Test on 1/2 " OD X .049 at 45°

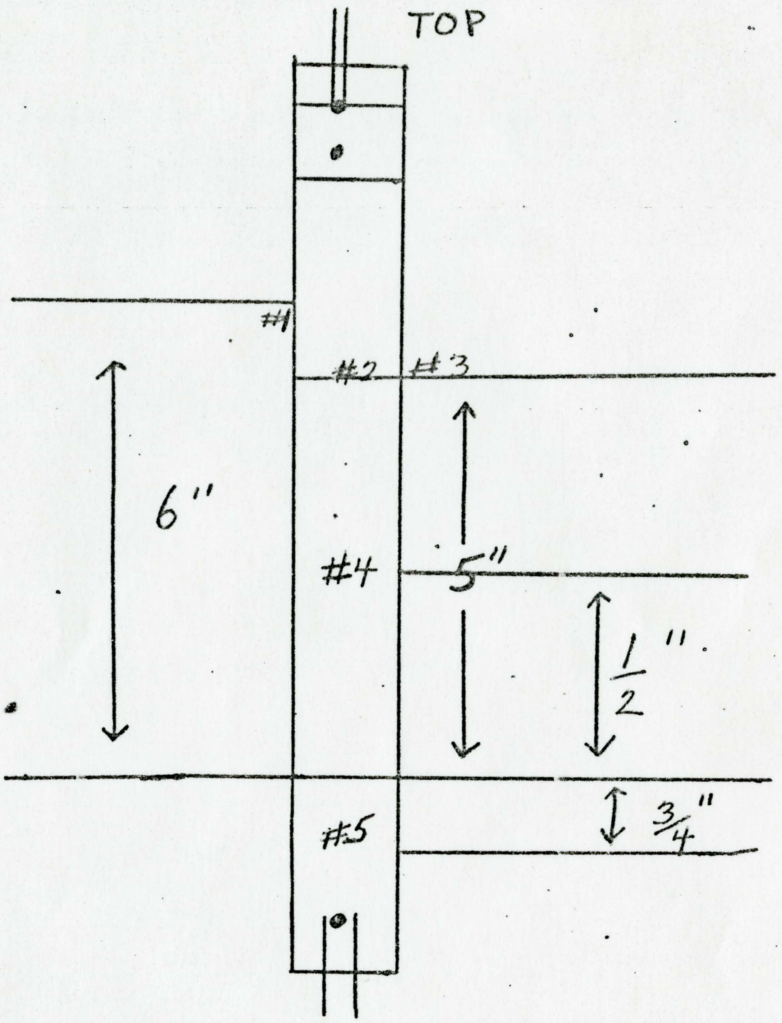


Gage No.	Reading(lbs)	Strain or comp.	deflection
	50	135	.0155"
	100	268	.038
	150	405	.0615
# 1	200	223	.0875
	250	150	.13
	300	90	.43
	500	94	.76
	50	532	
	100	1080	
	150	1652	
# 2	200	2020	
	250	2549	
	300	3104	
	500	6100	
	50	320	
	100	665	
	150	1010	
# 3	200	1360	
	250	1693	
	300	2028	
	500	3430	

Tensil Test on 1 1/2 " OD X .049 at 45°

Gage No.	Reading (lbs)	Strain	Micro inches/inch	
	50	35		
	100	54		
# 1	150	78		
	200	100		
	250	123	1500	678
	50	14		
	100	40		
# 2	150	67		
	200	80		
	250	88	1500	512
	50	30		
	100	52		
# 3	150	78		
	200	95		
	250	118	1500	660
	50	22		
	100	24		
# 4	150	25		
	200	24		
	250	22	1500	306
	50	10		
	100	10		
# 5	150	10		
	200	10		
	250	10	1500	178

Tensil test



January 27, 1980

I test flew a glider with a new 25 front keel and 5 aft keel, with 25 cross tube. I had two good long flights and the glider did feel 4 lbs lighter.

February 9, 1980

I test flew a glider with new graphite leading edges. I had a good flight and it held up good.

SENSOR 510 - HEEL - 1 REQUIRED

$$\frac{EI}{10^6} = 34\left(\frac{\pi}{64}\right)\left(D^4 - d^4\right)$$

($E_{GR.} = 34 \times 10^6$ PSI

$E_{AL} = 10 \times 10^6$ PSI)

$$\left(D^4 - d^4\right)_{GR} = \frac{10}{34}\left(D^4 - d^4\right)_{AL}$$

$$\frac{10}{34}\left(D^4 - d^4\right) = K$$

$$\frac{10}{34}(1.625)^4 - (1.527)^4 = K$$

$$\frac{10}{34}(6.973) - (5.437) = 1.536\left(\frac{10}{34}\right) = \quad K = .452$$

$$d^4 = D^4 - K$$

$K = .452$

$$d^4 = (1.625)^4 - .452$$

$$d^4 = 6.973 - .452 = 6.521$$

$$d = (6.521)^4 = 1.598$$

$d = 1.598$

O.D. GR. = 1.625"

I.D. = 1.598

.027

WALL TK = .0135" FOR D-C
SECT

SENSOR 510 KEEL CONT.

FOR SRC BED.

$$\frac{10}{34}(D^4 - d^4) = k$$

$$\frac{10}{34}(1.625)^4 - (1.411)^4 = k$$

$$\frac{10}{34}(6.973) - (3.964) = k$$

$$\frac{10}{34}(3.009) = k$$

$$.885 = k$$

$$d^4 = D^4 - k$$

$$d^4 = (1.625)^4 - .885$$

$$d^4 = 6.973 - .885 = 6.118$$

$$d = (6.118)^4 =$$

$$d = 1.573''$$

O.D. $_{SR}$ = 1.625.
I.D. = 1.573
.052

WALL TK. = .026" / FOR SRC BED

SENSOR 510 - HEEL - 1 REQUIRED

$$\frac{EI}{10^6} = 34\left(\frac{\pi}{64}\right)\left(D^4 - d^4\right)$$

($E_{GR} = 34 \times 10^6$ PSI

$E_{AL} = 10 \times 10^6$ PSI)

$$\left(D^4 - d^4\right)_{GR} = \frac{10}{34}\left(D^4 - d^4\right)_{AL}$$

$$\frac{10}{34}\left(D^4 - d^4\right) = K$$

$$\frac{10}{34}(1.625)^4 - (1.527)^4 = K$$

$$\frac{10}{34}(6.973) - (5.437) = 11.53.6\left(\frac{10}{34}\right) = \quad K = .452$$

$$d^4 = D^4 - K$$

$K = .452$

$$d^4 = (1.625)^4 - .452$$

$$d^4 = 6.973 - 452 = 6.521$$

$$d = (6.521)^4 = 1.598$$

$d = 1.598$

O.D. GR. = 1.625"

I.D. = 1.598

.027

WALL TK = .0135" FOR A-C
SECT

GRAPHITE TEST

WT. DEF.

AL - TEST

WT. DEF.

TVD
3/7/83

1 Side tube

—

Braid 4 – 8 layers { 40 ends 12K PAN Graphite
40 ends S2CG150 1/3 x 2

75% graphite 25% glass

Weight of tube 5# 3oz 20" LOA
" " 2WD " = 4.875 #s (est. 4.7)

Resin ~ 50% by weight 250°F Film adhesive

– wedge on mandrel slipped out on outboard 3' carbon fold in cloth – cut off & will be repaired

Diameter ID 1.875
OD 1.98" → 2.15"

SPECIAL GRAPHITE FOR COMPRESIVE STRENGTH
MODULUS 70% higher THAN GRAPHITE
FOR BENDING & TENSION MODULUS

Material furnished by Blool

2" × 049 — 35.00

~~18'~~ 1 7/8" -.055 TUBING ~~18~~ 28' ~~40.00~~ 52.00

1 1/2 × 049 × 12' — 21.00

1" × 049 × 12' — 14.00

3" × 065" — 57.60 ES

1 - LOADING BOOM — 189.50

1.90" × 20' AL PIPE — 63.60 ES.

1/2" × 1/4" STEEL 2 PCS. — 10.00

1 1/2" PVC PIPE = 2.99

2 - 12' LGN. 3/16" SQ STOCK

(122.00)

(134.19)

-200.00 DP

~~865.81~~

665.81

766.0

638.31
117.30
755.61

85.00
92.00
177.00

TVD
2/22/83

CROSS - Side tube

Built to replace

9'7" × 2½ OD × .049 aluminum

.444 #/ft 19'2" ⇒ 8.51 # 9.27 w/inserts

$E = 34 \times 10^6$
$\sigma = 425{,}000$ psi

Side tube of graphite = 60% GR

5 layers { 40 end 12K PAN graphite SG = 1.9
80 ends Sglass S2GG150 1/3×2 SG = 2.5

$\sigma = 665{,}000$ psi
$E = 12.4 \times 10^6$

Weight of 1 tube

5 # 6 oz w/ reinforcing layers or 5.375 #s

Weight Saving 3.14 # − 37% w/o insert

3.09 # = 42% w/o insert

4 layers of Braid gives the same EI as the above aluminum tube therefore the 5 layers give 25% higher EI.

Diameter of Tube = 2½" ±.020"

Ends of tube are reinforced w/ 2 extra layers

estimate wall thickness to be .060"

Estimate for L.E. tube.

weight each 4.7 # 2.1" OD

replace 9.2 #

KEEL

Bushed with arrow shaft 1¼ DIA WT = 3.13/15

white plastic

SENSOR 510 - HEEL - 1 REQUIRED

$$\frac{EI}{10^6} = 34\left(\frac{\pi}{64}\right)\left(D^4 - d^4\right)$$

$$\left(E_{GR.} = 34 \times 10^6 \text{ PSI}\right.$$
$$\left.E_{AL} = 10 \times 10^6 \text{ PSI}\right)$$

$$\left(D^4 - d^4\right)_{GR} = \frac{10}{34}\left(D^4 - d^4\right)_{AL}$$

$$\frac{10}{34}\left(D^4 - d^4\right) = K$$

$$\frac{10}{34}(1.625)^4 - (1.527)^4 = K$$

$$\frac{10}{34}(6.973) - (5.437) = 1.536\left(\frac{10}{34}\right) = \boxed{K = .452}$$

$$d^4 = D^4 - K$$

$$\underline{K = .452}$$

$$d^4 = (1.625)^4 - .452$$

$$d^4 = 6.973 - .452 = \underline{6.521}$$

$$d = (6.521)^4 = 1.598$$

$$\underline{d = 1.598}$$

O.D. GR. = 1.625"
I.D. = 1.598
.027

WALL TH = .0135" FOR D-C
SECTI

SENSOR 510 KEEL CONT.

FOR SEC B-B D.

$\frac{10}{34}(D^4 - d^4) = k$

$\frac{10}{34}(1.625)^4 - (1.411)^4 = k$

$\frac{10}{34}(6.973) - (3.964) = k$

$\frac{10}{34}(3.009) = k$

$.885 = k$

$d^4 = D^4 - k$

$d^4 = (1.625)^4 - .885$

$d^4 = 6.973 - .885 = 6.118$

$d = (6.118)^4 =$

$d = 1.573"$

O.D. GR = 1.625.
I.D. = 1.573
.052

WALL TK = .026" / FOR SEC B-B D

SENSOR 510 KEEL CONT.

FOR SRC BOD.

$$\frac{10}{34}(D^4 - d^4) = k$$

$$\frac{10}{34}(1.625)^4 - (1.411)^4 = k$$

$$\frac{10}{34}(6.973) - (3.964) = k$$

$$\frac{10}{34}(3.009) = k$$

$$1.885 = k$$

$$d^4 = D^4 - k$$

$$d^4 = (1.625)^4 - .885$$

$$d^4 = 6.973 - .885 = 6.118$$

$$d = (6.118)^4 =$$

$$d = 1.573''$$

O.D. $_{GR}$ = 1.625.
I.D. = 1.573
.052

WALL THK = .026" / FOR SRC BOD

SENSOR 510 KEEL CONT.

FOR SEC B&D.

$\frac{10}{34}(D^4 - d^4) = k$

$\frac{10}{34}(1.625)^4 - (1.411)^4 = k$

$\frac{10}{34}(6.973) - (3.964) = k$

$\frac{10}{34}(3.009) = k$

$.885 = k$

$d^4 = D^4 - k$

$d^4 = (1.625)^4 - .885$

$d^4 = 6.973 - .885 = 6.118$

$d = (6.118)^4 =$

$d = 1.573"$

$O.D_{ft} = 1.625$

$I.D. = \underline{1.573}$

$.052$

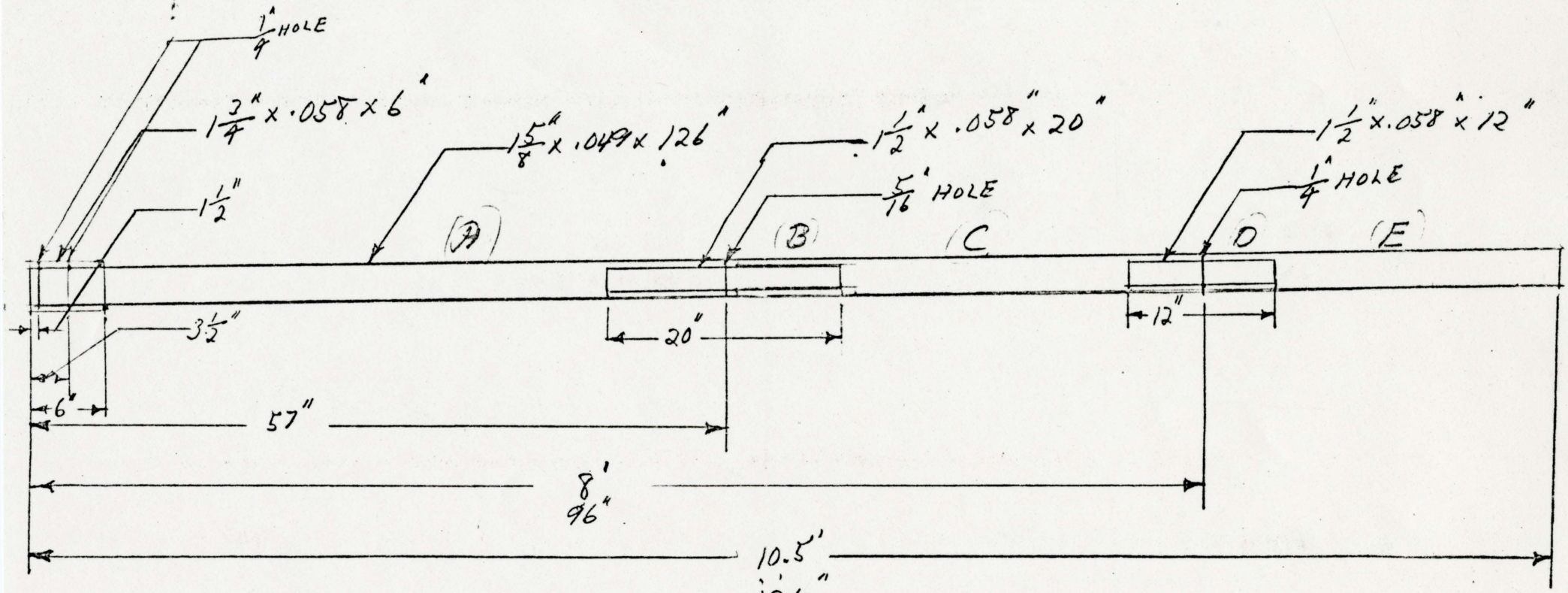
WALL TK = .026" / FOR SEC B&D

Peggy Bell ✓
Lisa Lofaro ✓
Lisa ✓
Sue ✓
Nancy Polanco ✓
Lorraine Chin ✓
Terry Fratol ✓
Eileen ✓
Anita Gerhardt ✓
Claudia Bourque ✓
Marjorie Takeuchi ✓
Chris Talbot ✓
Evie Wisnoski ✓
Silvia Healy ✓

Gloria ✓
Chris Budis ✓
Pam Copley ✓
Karen Vole ✓
Deb Dasken ✓
Liz Stautial
Connie ✓
Cathy ~~Fox~~ Fox ✓
Sue Williams ✓
Ann Dimpoly

SENSOR 510 KEEL

1-REQUIRED



SUGGEST TO REPLACE WITH EQUIVALENT GRAPHITE SPAR TAPERED FROM $2\frac{1}{2}$" OD TO $1\frac{3}{4}$"

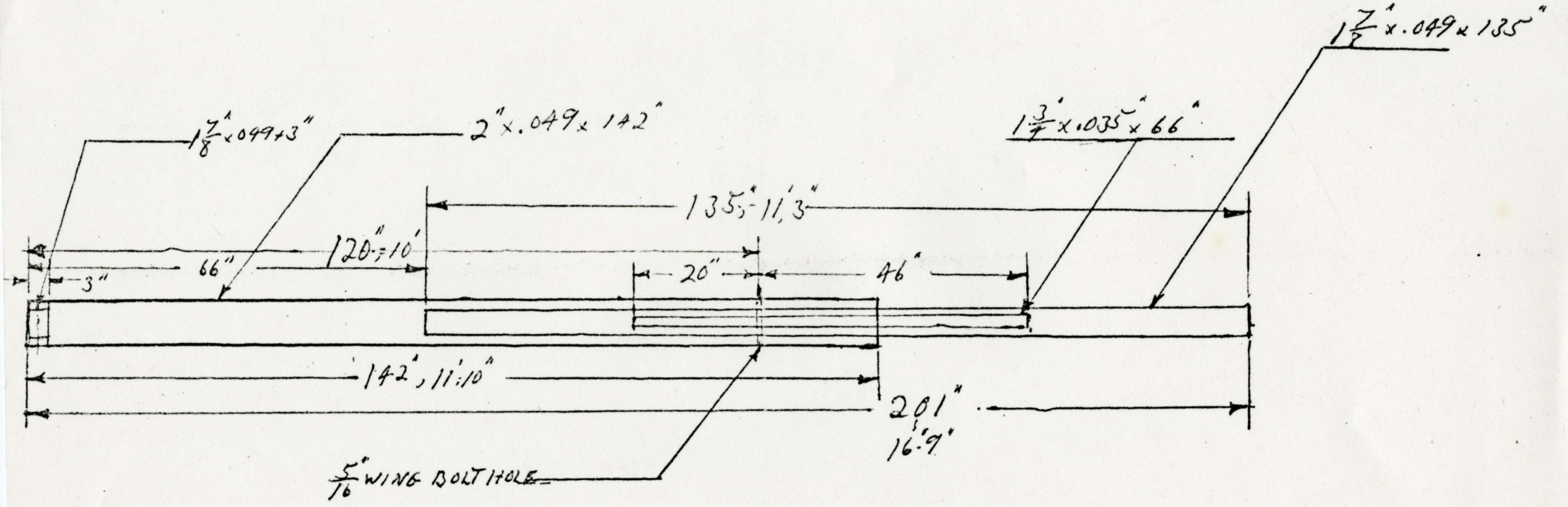
BOND GLIDER SENSOR 510 LEADING EDGE

(2) REQUIRED

SCALE: $\frac{1}{2}$" = 1'

WT. = 9.2 lbs/LE.

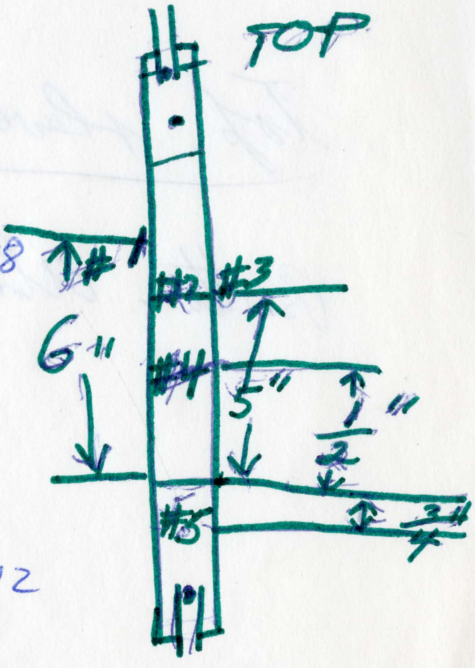
OR 18.4 lbs FOR (2)



TENSILE TEST ON 1½" OD x .049 = 45°

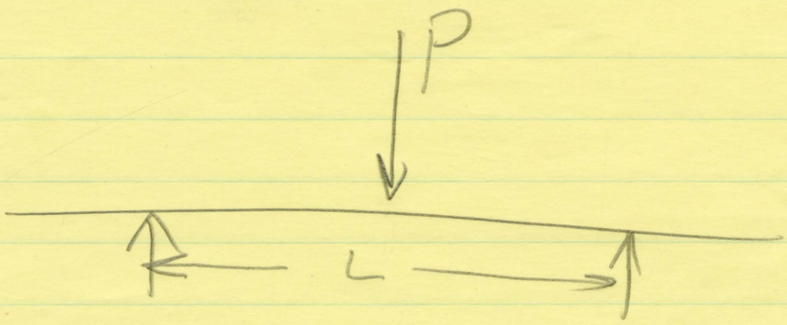
MICRO INCHES / inch

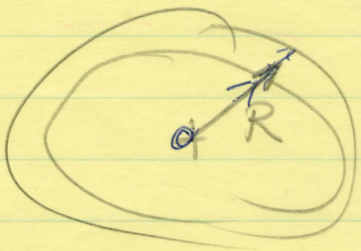
GAGE NO.	LBS READING	STRAIN
#1	50	35
	100	54
	150	78
	200	100
		123
		1500 678
#2	50	14
	100	40
	150	67
	200	80
		88
		1500 512
#3	50	30
	100	52
	150	78
	200	95
		118
		1500 660
#4	50	22
	100	24
	150	25
	200	24
		22
		1500 306
#5	50	10
	100	10
	150	10
	200	10
		10
		1500 178



Top sleeve let go 1715 1655

Bottom sleeve ~~bolt~~ hole let go 2165





Def $y_{max} = \frac{PL^3}{48EI}$

$I = \pi R_{avg}^3 t$

$E = \frac{PL^3}{48 I y_{max}} = \frac{}{1.3555} = 8.52 \times 10^6$

$E = \frac{PL^3}{48 y_{max} \pi R_{avg}^3 t}$ $\frac{}{1.2897}$

$E_{al} = 10 \times 10^6$ psi ← 8.95×10^6

$S_{st} = 30 \times 10^6$ psi

$P = 104.375$ lb

$L = 48''$

$R = .75''$

$T = .049''$

$I = 6.49 \times 10^{-2}$

768.069

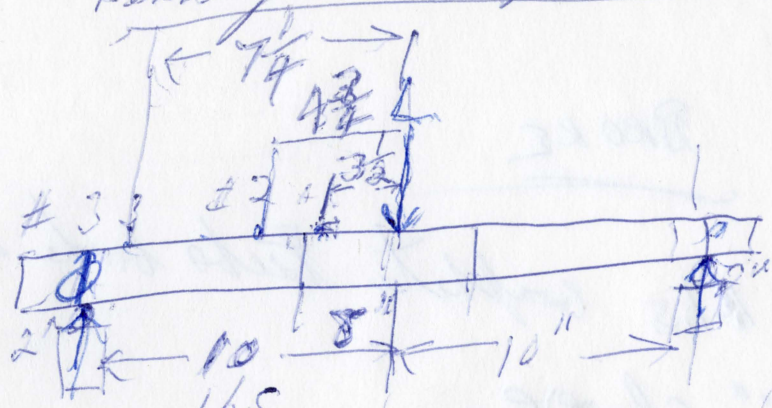
329.029

BROKE

1015 lbs complete Tube body at
8" sleeve

1150# AL

Bending test on 1/2" OD x .049 - 45°



Rod No.	Reading	Strain at Comp	Def.
#1	50	135	.0155
	100	268	.038
	150	405	.0615
	200	223	.0875
	250	150	.13
	300	90	.43
	500	94	.76
#2	50	532	
	100	1080	
	150	1652	
	200	2020	
	250	2549	
	300	3104	
	500	6100	
#3	50	320	
	100	665	
	150	1010	
	200	1360	
	250	1693	
	300	2028	
	500	3430	

FOR $D = 2\frac{1}{2}"$ SENSOR-510 CROSS-TUBE "2" REQUIRED

$$\frac{EI}{10^6} = 34\left(\frac{\pi}{64}\right)(D^4 - d^4)$$

$(E_{GR.} = 34 \times 10^6$ PSI
$E_{AL} = 10 \times 10^6$ "$)$

$$(D^4 - d^4)_{GR.} = K = \frac{10}{34}(D^4 - d^4)_{AL} = K$$

$D^4 - d^4 = K$

$d^4 = D^4 - K$

$$\frac{10}{34}D^4 - d^4_{AL} = K$$

$(2.5)^4 - (2.402)^4 = K$

$39.06 - 33.67 \quad \frac{10}{34}(5.37) = 1.585 = K$

$d^4 = D^4 - K$

$K = 1.585$

$d^4 = (2.5)^4 - 1.584$

$d^4 = 39.06 - 1.584 = 37.476$

$d = (37.476)^4$

$d = 2.474"$

O.D. GR = 2.500" OD

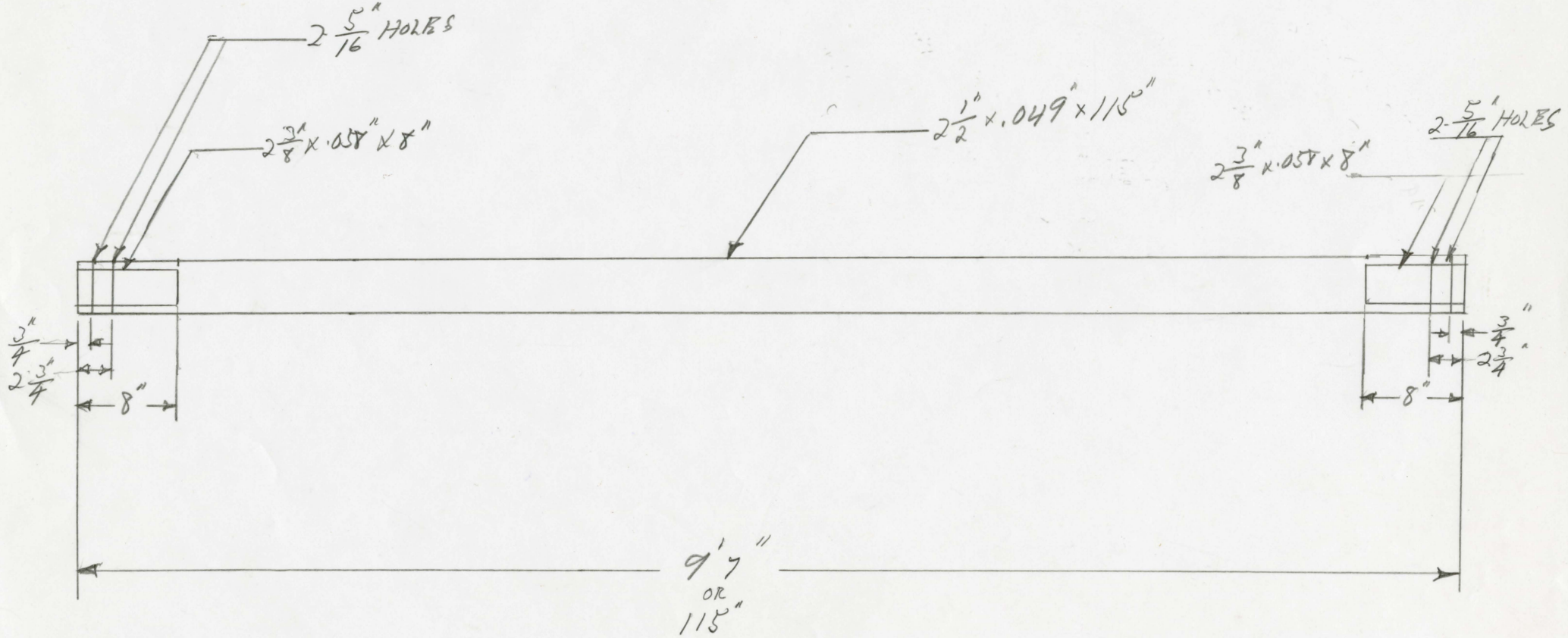
I.D. 2.474 ID

0.026"

WALL THICKNESS = .013"

SENSOR-510-CROSSTUBE

2- REQUIRED



SENSOR 510 - HEEL - 1 REQUIRED

$$\frac{EI}{10^6} = 34\left(\frac{\pi}{64}\right)\left(D^4 - d^4\right)$$

($E_{GR.} = 34 \times 10^6$ PSI

$E_{AL} = 10 \times 10^6$ PSI)

$$\left(D^4 - d^4\right)_{GR} = \frac{10}{34}\left(D^4 - d^4\right)_{AL}$$

$$\frac{10}{34}\left(D^4 - d^4\right) = K$$

$$\frac{10}{34}(1.625)^4 - (1.527)^4 = K$$

$$\frac{10}{34}(6.973) - (5.437) = 11.53.6\left(\frac{10}{34}\right) = \quad K = .452$$

$$d^4 = D^4 - K$$

$K = .452$

$$d^4 = (1.625)^4 - .452$$

$$d^4 = 6.973 - .452 = 6.521$$

$$d = (6.521)^4 = 1.598$$

$d = 1.598$

O.D. GR. = 1.625"

I.D. = 1.598

.027

WALL TK = .0135" FOR A-C SECTION

SENSOR 510 - KEEL - 1 REQUIRED

$$\frac{EI}{10^6} = 34\left(\frac{\pi}{64}\right)\left(D^4 - d^4\right)$$

$$\left(E_{6n.} = 34 \times 10^6 \text{ - PSI}\right.$$

$$\left.E_{DL} = 10 \times 10^6 \text{ PSI}\right)$$

$$\left(D^4 - d^4\right)_{6n} = \frac{10}{34}\left(D^4 - d^4\right)_{DL}$$

$$\frac{10}{34}\left(D^4 - d^4\right) = K$$

$$\frac{10}{34}(1.625)^4 - (1.527)^4 = K$$

$$\frac{10}{34}(6.973) - (5.437) = 1.536\left(\frac{10}{34}\right) = \quad K = .452$$

$$d^4 = D^4 - K$$

$$K = .452$$

$$d^4 = (1.625)^4 - .452$$

$$d^4 = 6.973 - .452 = 6.521$$

$$d = (6.521)^4 = 1.598$$

$$d = 1.598$$

O.D. 6n. = 1.625"

I.D. = 1.598

.027

WALL TK = .0135" FOR D-C & E SECTION

GRAPHITE

2.1" = 3.75 lbs.

17/8" = 5.75 lbs.

25% down payment

$200.00

GRAPHITE .75-80%

S-GLASS

("Better impact)

20° CANSOA 510

Battens - SHAPE

Leading Edge $189.00 Complete.

BOTTOM CAN THEY BE FLAT

Hdw.: Sleeves TIP ADAPTER.

1/2 set of Battens

1/4 x .035" 7/8" + 3/8"

3

WT. 510 CANSOA LEADING EDGE

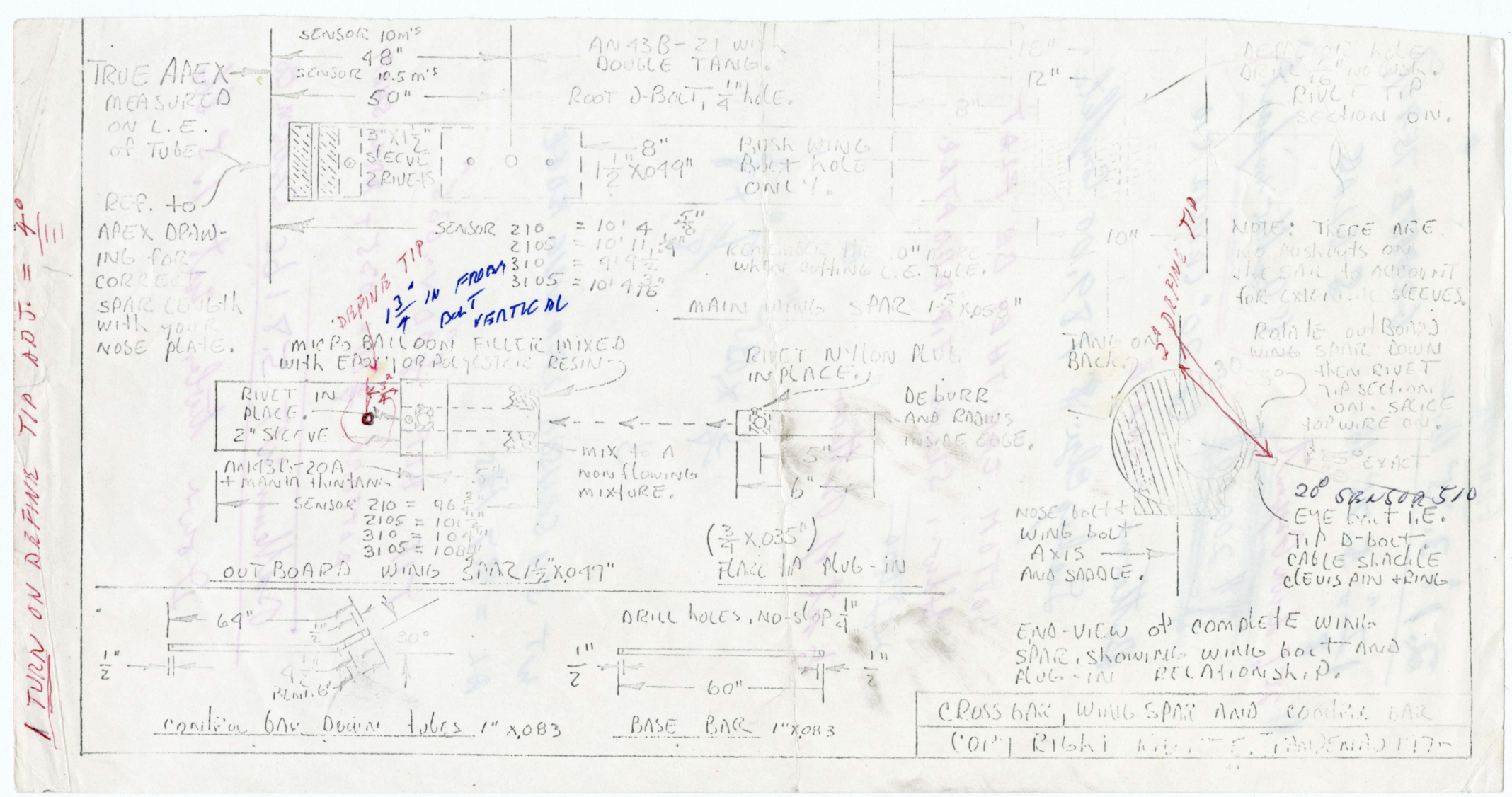
AL = 9.7 lbs.

TIP ADP. 7/8" OD x .035"

BATTENS 3/8 OD x .035 + ARROW SHAFT

Battens WT 5.8 lbs CANSOA CO

Down feather cut 1.5 lbs



1 TURN ON DEFINE TIP ADJ. = 1°/111

NOTE

I have been working for the past two years with a graduate student, Craig Douglas, on graphite designed tubing for my Sensor 210 D-165, with Bob Trampenau's permission of course. We had about $ 3000 worth of graphite tubing. It was 2" and 1 1/2" X .050" wall thickness, 6' lengths, and spun in different weaves from 5° -90°, which governs the stiffness or flexibility of the tubes. With Bob's reccomendation we used the 2" on the leading edges and 1 1/2" on the keel and cross tube. We did bending tests on all the different angles the tubes were spun at. (Results are enclosed with this material). We found that the 25° graphite was about the same stiffness as the Aluminum. We used 25° on the forward keel, 5° on aft keel, 25° on the crossmember and 30° on the 2" leading edges. The tubes were sleeved and bushed wherever there was a bolt or splice with stainless steel bushing or anodized aluminum sleeves. The tubes were joined by sleeves with 2 ton 1/2 hour epoxy glue.

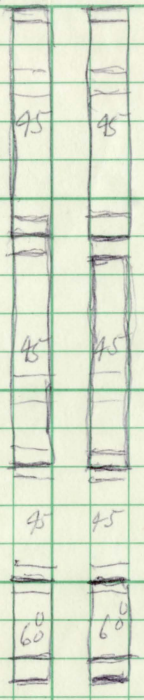
The College of Engineering has allowed me to work on this project for the past year, ~~during working hours~~. Since they paid for all the tubing, I furnished the money for all the new hardware (sail and all anodized sleeves and other parts cost me $550) First, I replaced the keel with graphite on my glider and flew it, next the crossmember, and finally the leading edges. After all the tubes were replaced I bought a new white sail, fitting it with all new parts. I then put all the aluminum back onto the old glider. It was a step by step operation. The weight reduction was not as much as I expected because the leading edges were 1 5/8" and ~~about~~ 1 1/2" replaced by 2" graphite. Tube for tube it is just about 40% lighter and twice as strong. In tension tests the bolts pulled right through the Aluminum sleeves that were epoxied onto the graphite. The glider at the start weighed 51 pounds, while after conversion it weighed only 45 pounds. The sail weight was 10 pounds, the control bar, king post, deflexor, define tips and battens about 10 pounds. I have ordered a control bar, king post and defined tips in graphite also, and they should reduce the weight by about 5 pounds more. The College of Engineering is also paying for more graphite tubing, 1 7/8" and 1 5/8" for a deflexorless, Sensor 510.

ENCLOSER 1

UP Products Testing New Graphite Glider
Hang Gliding Magazine, november 1977,p. 13

Very favorable flight tests have been completed on a new Ultralight Products glider. For comparison purposes, UP built their prototype to the same specs as their " 154 " Spyder, but used graphite spars instead of aluminum. The graphite tubing used was made by Graftek/Exxon's Marine Products division. These shiny, dark grey spars are made by wrapping epoxy impregnated graphite material over long mandrels and then firing them under heat and pressure to achieve the proper cure and strength. The result: tubes with half the weight and twice the strength of aluminum!The advantages of this material will enable manufacturers to create smaller gliders having the same lift capabilities as the larger, heavier aluminum gliders. With the reduction in span comes a proportional increase in penetration and quicker control response. The disadvantage of the graphite composite tubes are expense; about $ 1000 more per glider than aluminum, and a slower fabrication time. Costlier tools are needed; diamond tipped saws and drills must be used to cut and pierce the spars. Construction techniques must be streamlined. According to UP President, Pete Brock, " We are working on a solution to these problems and are confident that we will have the first production graphite Spyders and Fireflys in the hands of the public by next year. " Brock feels that graphite will be to the hang gliding industry what urethane foam was to the surfing industry.

$1\frac{1}{2}$" LEADING EDGE

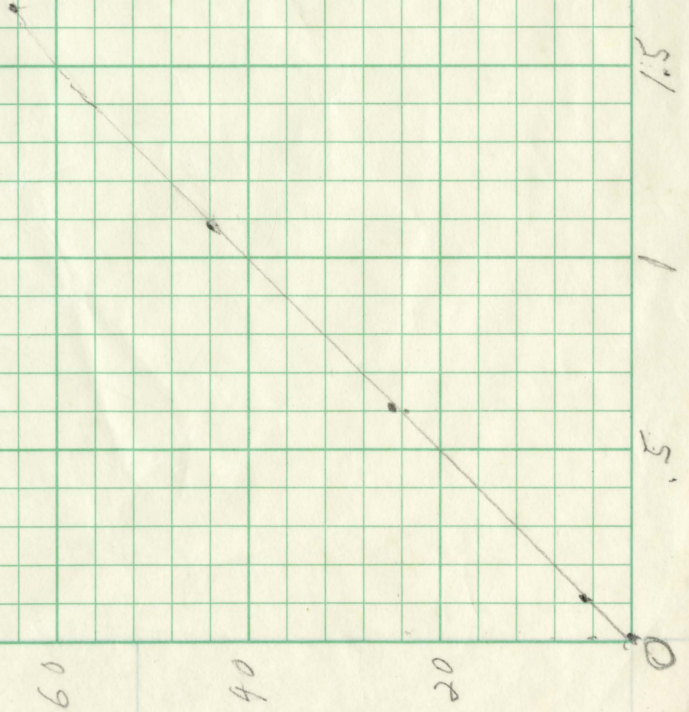


1 = 12" $1\frac{5}{8}$ x 0.49" SLEEVE

2 = 3" " " "

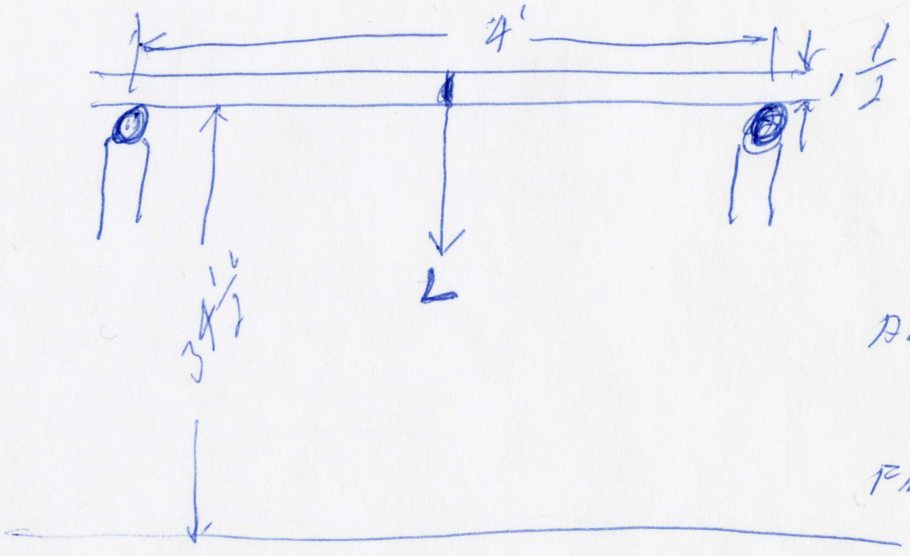
2 = 4" " " "

8 = 8' " " "



11 June 80

YIELD LOAD

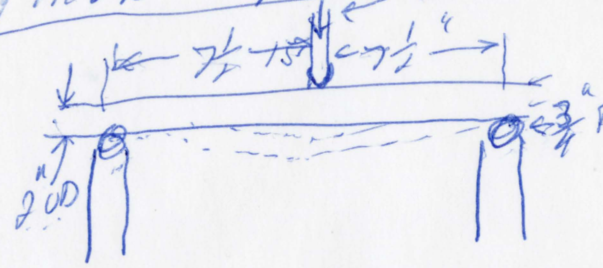


DL 1 1/2" x .049
6061

FAILED

GRAPHITE 1 1/2" x .050"
45°
240 lbs
LOT OF DEFLECTION
LIKE BOW
WERE ABLE
TO STRAIGHTEN
OUT AGAIN

YIELD TEST LOAD



WT al Down tube
Kinky foot DRAWN TIPS 6.5 lbs

WT OF DEF. BATTRASS 3.5 lbs

TOTAL 10 lbs

11 OUNCE TO

(AL PIPE 2" x .058"
- 6061 T6
(1050 lb
FAILED
(DEF. 1½")

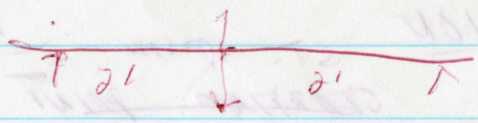
(GRAPHITE 2" .050
35°

FAILED AT 425 lbs

(INDENTED AT 300 lb

aluminum

.049 1½" .003 ≠ 25°



TEMP. —

STIFFNESS

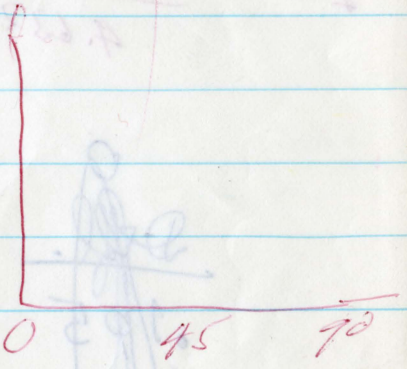
WEAVE ANGLE

at 0 —

DEF. 1.540

$E = 8.52 \times 10^6$

WT.	DEF.
4lb 6oz	1.570
24 " "	1.630 1.629
44 " "	1.724
64 " "	1.800
84 " "	1.876
104 " "	1.975

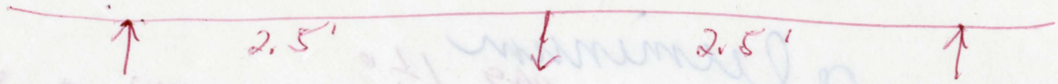


Δ L.

.049 × 1.5"

WT.	DEF.
0	~~1.573~~
4lb 6oz	1.610
24 " "	1.690
44	1.767
64	1.834
84	1.927
104	1.987

$E = 7.95 \times 10^6$



6' LGN
1½ OD .0492
.004 - #45°

DEFLEXION — ST. POM — LOAD

1.695 — 0

1.540 — STARTING POINT — 4 lbs 6 OZ

1.051 — 24 lbs 6

.547 — 44 " 6"

.000 — 64 .. 6"

1.645"
547
1.098

$E = \frac{216000}{4.63^2}$

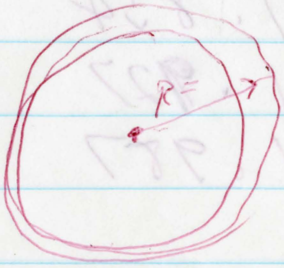
1.645
1.051
.594

1.645
1.540
.105

Defl.	Wt.		Defl.
.105	4# 6oz.	–	.105
.489	24# 6oz.		.594
.504	44# 6oz.	–	1.098"
.547	64# 6oz.		1.645"

$E = \frac{8046.875}{.008035}$

E = 1002101.4



R = .725

P = 64.375 lb

I = .0576622

$\frac{PL^3}{\max} = \frac{8046.875}{}$

Tensil Test on 1 1/2 " OD X .049 at 45°

Gage No.	Reading (lbs)	Strain	Micro inches/inch	
	50	35		
	100	54		
# 1	150	78		
	200	100		
	250	123	1500	678
	50	14		
	100	40		
# 2	150	67		
	200	80		
	250	88	1500	512
	50	30		
	100	52		
# 3	150	78		
	200	95		
	250	118	1500	660
	50	22		
	100	24		
# 4	150	25		
	200	24		
	250	22	1500	306
	50	10		
	100	10		
# 5	150	10		
	200	10		
	250	10	1500	178

Graphite

$1\frac{1}{2} \times .050'' - .006 \pm 5°$

$1\frac{1}{2}'' \times .006 \pm 5°$ — 2 - CREAKING NOISES

WT.	DEF
0	1.531
4lb - 6oz	1.560
24 " -1	1.604
44	1.660
64	1.717
84	1.776
104	1.810
124 " 64	1.858

$E = \frac{PL^3}{48 y_{Max} \pi R^3 avg\ T}$

$E = 14.31 \times 10^6$

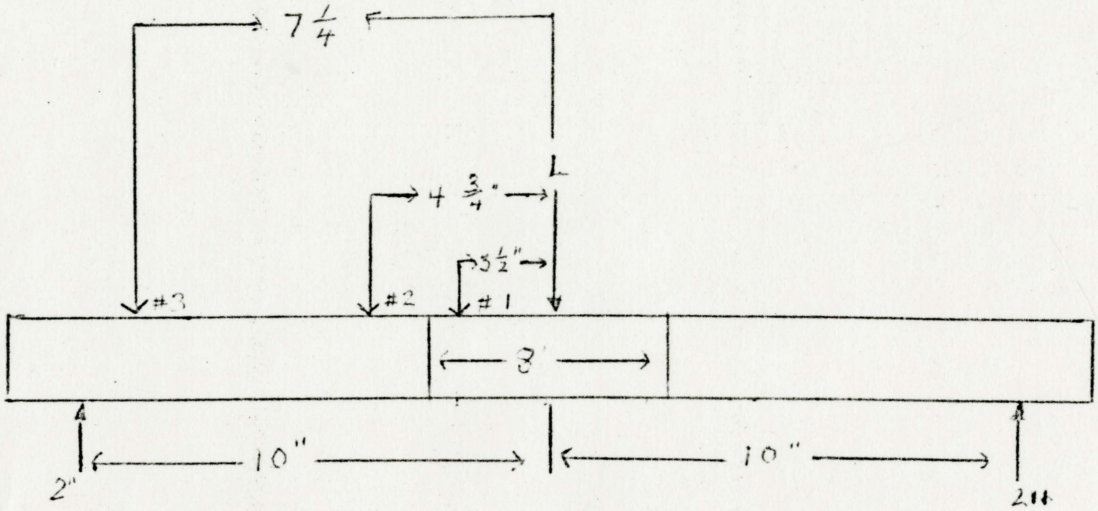
~~$E = 14.37 \times 10^6$~~

$1\frac{1}{2}'' .004 \pm 45°$

WT.	DEF
0	1.591
4lb 6o	1.626
24	1.862
44	2.128
64	2.370
84	2.653
104	2.964

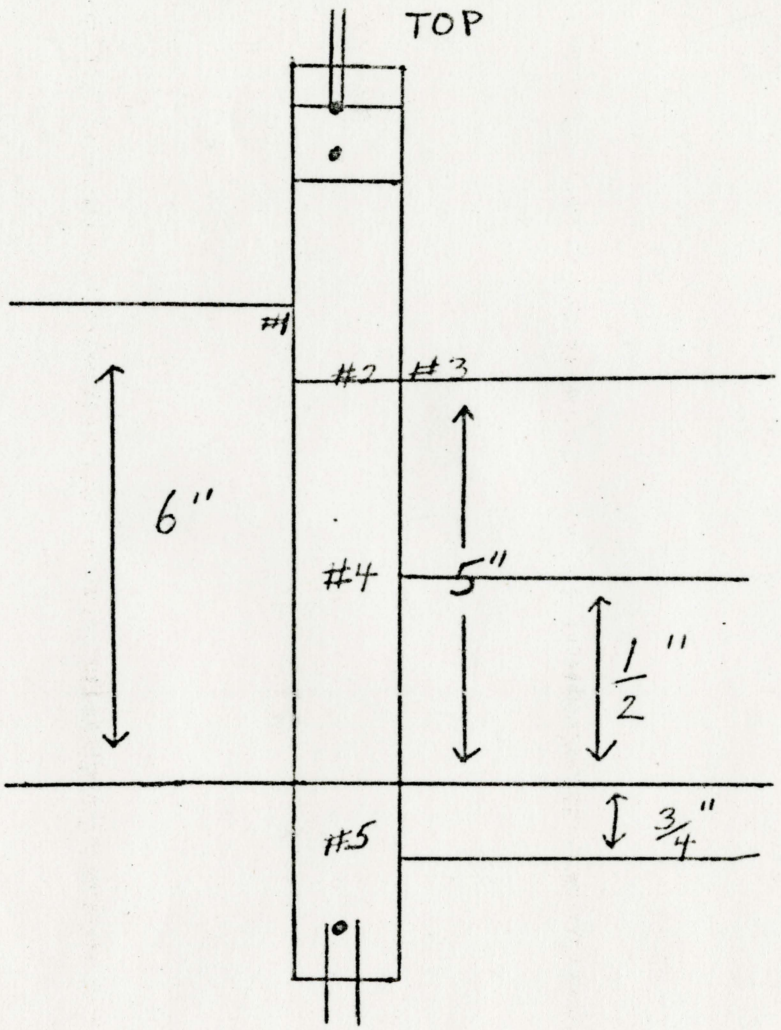
$E = 2.7 \times 10^6$

Bending Test on 1/2 " OD X .049 at 45°

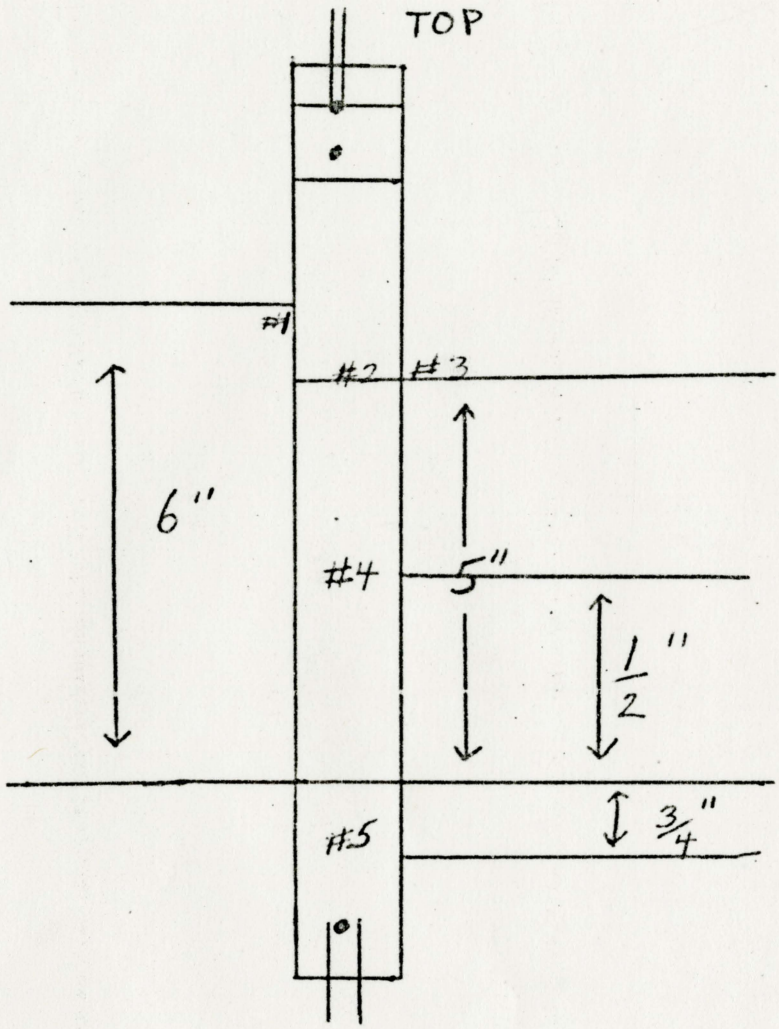


Gage No.	Reading(lbs)	Strain or comp.	deflection
	50	135	.0155"
	100	268	.038
	150	405	.0615
# 1	200	223	.0875
	250	150	.13
	300	90	.43
	500	94	.76
	50	532	
	100	1080	
	150	1652	
# 2	200	2020	
	250	2549	
	300	3104	
	500	6100	
	50	320	
	100	665	
	150	1010	
# 3	200	1360	
	250	1693	
	300	2028	
	500	3430	

Tensil test



Tensil test



University of Lowell
One University Avenue
Lowell, Massachusetts 01854
(617) 454-7811

27 Jan 80.

Test flew glider with new 25° front heel and 5° aft. heels, with 25° Gas tube, had two good long flight, glider did feel 4 lbs lighter.

9, FEB, 80

Test flew glider with new G.R leading edges good flight held up good.

ALUMINUM TESTS

1 1/2" X .049"

Weight	Deflection
0	1.573
4 lbs 6 oz.	1.610
24 lbs 6 oz.	1.690
44 lbs	1.768
64 lbs	1.834
84 lbs	1.927
104 lbs	1.987

$$E = \frac{PL^3}{48\ y\ Max\ M\ R^2 avg\ t}$$

$$E = 8.95 \times 10^6$$

18 Jan. 1980

TUBING COMPARISON

Keel-aluminum	Weight--- 1983 grams or 4.37 pounds
Keel-graphite	Weight---1180 grams or 2.60 pounds
Cross tube-aluminum	Weight--- 1297 grams or 2.86 pounds
Cross tube-graphite	Weight--- 877 grams or 1.93 pounds

Leading edge

Aluminum (1 5/8"& 1 1/2")	Weight--- 2782 grams or 6.13 pounds
Graphite (2")	Weight--- 2603 grams or 5.73 pounds

GRAPHITE TESTS

1 1/2" X .050"+.006 ±5°

Weight	Deflection
0	1.551
4 lbs-6 oz.	1.560
24 lbs-6 oz.	1.604
44 lbs	1.660
64 lbs	1.717
84 lbs	1.776
104 lbs	1.810
124 lbs-6 oz.	1.858

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^4 avg.\ t}$$

$$E = 14.31 \times 10^6$$

1 1/2" X .050"-.004 ±45°

Weight	Deflection
0	1.571
4 lbs-6 oz.	1.626
24 lbs	1.862
44 lbs	2.128
64 lbs	2.370
84 lbs	2.653
104 lbs	2.964

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^4 avg\ t}$$

$$E = 2.7 \times 10^6$$

1 1/2" X .050"-.003 ± 25°

Weight	Deflection
0	1.540
4 lbs 6 oz.	1.570
24 lbs 6 oz.	1.630
44 lbs 6 oz.	1.724
64 lbs 6 oz.	1.800
84 lbs 6 oz.	1.876
104 lbs 6 oz.	1.975

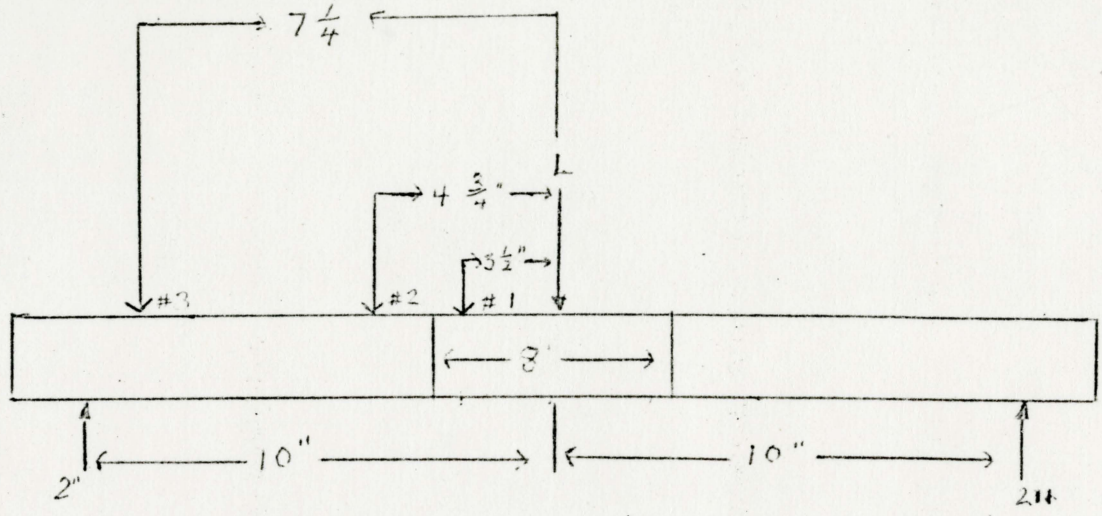
$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^4 avg\ t}$$

$$E = 8.52 \times 10^6$$

Tensil Test on 1 1/2 " OD X .049 at 45°

Gage No.	Reading (lbs)	Strain	Micro inches/inch	
	50	35		
	100	54		
# 1	150	78		
	200	100		
	250	123	1500	678
	50	14		
	100	40		
# 2	150	67		
	200	80		
	250	88	1500	512
	50	30		
	100	52		
# 3	150	78		
	200	95		
	250	118	1500	660
	50	22		
	100	24		
# 4	150	25		
	200	24		
	250	22	1500	306
	50	10		
	100	10		
# 5	150	10		
	200	10		
	250	10	1500	178

Bending Test on 1/2 " OD X .049 at 45°



Gage No.	Reading(lbs)	Strain or comp.	deflection
	50	135	.0155"
	100	268	.038
	150	405	.0615
# 1	200	223	.0875
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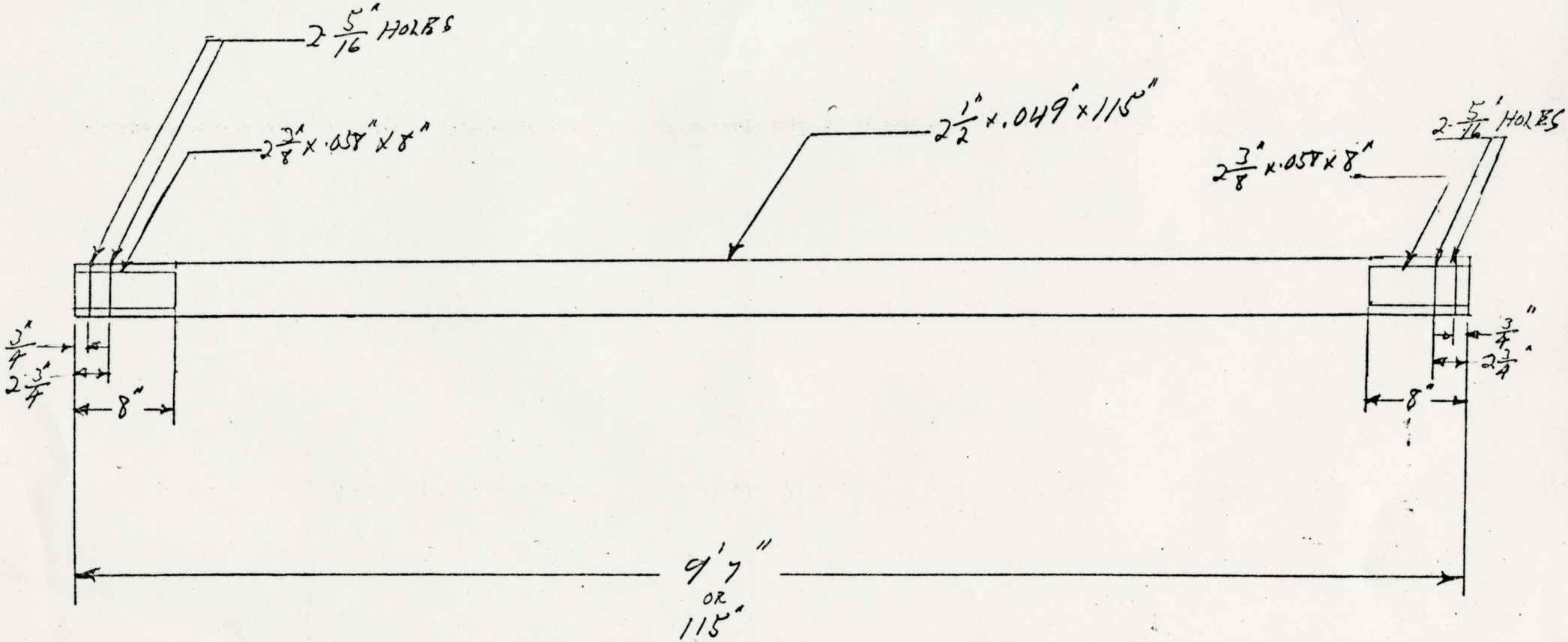
	300	90	.43
	500	94	.76
	50	532	
	100	1080	
	150	1652	
# 2	200	2020	
	250	2549	
	300	3104	
	500	6100	
	50	320	
	100	665	
	150	1010	
# 3	200	1360	
	250	1693	
	300	2028	
	500	3430	

SENSOR-510-CROSSTUBE

2- REQUIRED



GRAPHITE TESTS

1 1/2" X .050"+.006 ±5°

Weight	Deflection
0	1.551
4 lbs-6 oz.	1.560
24 lbs-6 oz.	1.604
44 lbs	1.660
64 lbs	1.717
84 lbs	1.776
104 lbs	1.810
124 lbs-6 oz.	1.858

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^4 avg.\ t}$$

$$E = 14.31 \times 10^6$$

1 1/2" X .050"-.004 ±45°

Weight	Deflection
0	1.571
4 lbs-6 oz.	1.626
24 lbs	1.862
44 lbs	2.128
64 lbs	2.370
84 lbs	2.653
104 lbs	2.964

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^4 avg\ t}$$

$$E = 2.7 \times 10^6$$

1 1/2" X .050"-.003 ± 25°

Weight	Deflection
0	1.540
4 lbs 6 oz.	1.570
24 lbs 6 oz.	1.630
44 lbs 6 oz.	1.724
64 lbs 6 oz.	1.800
84 lbs 6 oz.	1.876
104 lbs 6 oz.	1.975

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^4 avg\ t}$$

$$E = 8.52 \times 10^6$$

18 Jan. 1980

TUBING COMPARISON

Keel-aluminum	Weight--- 1983 grams or 4.37 pounds
Keel-graphite	Weight---1180 grams or 2.60 pounds
Cross tube-aluminum	Weight--- 1297 grams or 2.86 pounds
Cross tube-graphite	Weight--- 877 grams or 1.93 pounds

Leading edge

Aluminum (1 5/8"& 1 1/2")	Weight--- 2782 grams or 6.13 pounds
Graphite (2")	Weight--- 2603 grams or 5.73 pounds

#2 GRADUAT

WT.	DRF
0	70
10	69 1/4
30	68 1/4
50	67
70	66
90	65
110	64
130	63
150	62
170	61
190	60 1/2
190	60
200	59 1/2
210	59

WT of #2 TUBE
5.8 16s

18 Jan. 1980

TUBING COMPARISON

Keel-aluminum	Weight--- 1983 grams or 4.37 pounds
Keel-graphite	Weight---1180 grams or 2.60 pounds
Cross tube-aluminum	Weight--- 1297 grams or 2.86 pounds
Cross tube-graphite	Weight--- 877 grams or 1.93 pounds

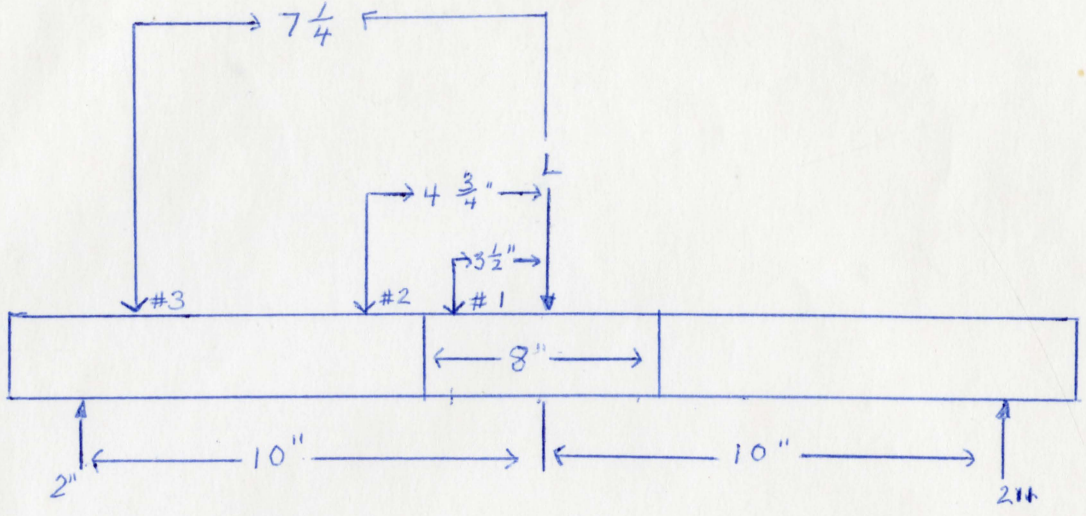
Leading edge

Aluminum (1 5/8"& 1 1/2")	Weight--- 2782 grams or 6.13 pounds
Graphite (2") &	Weight--- 2603 grams or 5.73 pounds

Tensil Test on 1 1/2 " OD X .049 at 45°

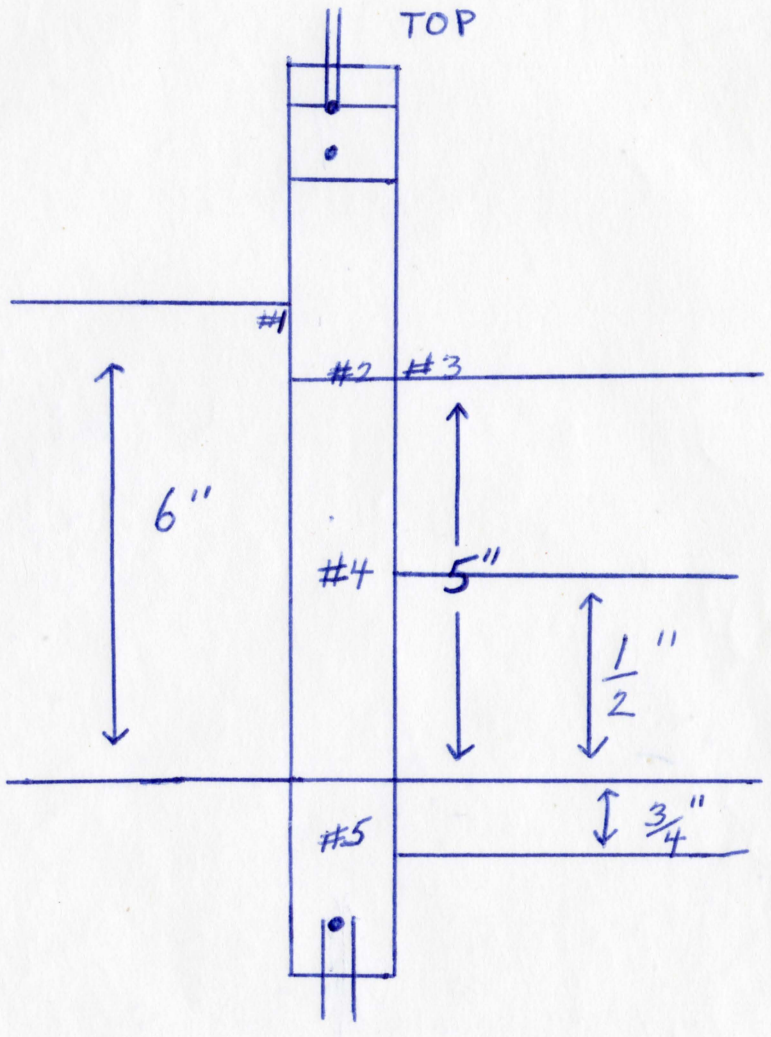
Gage No.	Reading (lbs)	Strain	Micro inches/inch	
	50	35	1500	678
	100	54		
# 1	150	78		
	200	100		
	250	123	1500	678
	50	14		
	100	40		
# 2	150	67		
	200	80		
	250	88	1500	512
	50	30		
	100	52		
# 3	150	78		
	200	95		
	250	118	1500	660
	50	22		
	100	24		
# 4	150	25		
	200	24		
	250	22	1500	306
	50	10		
	100	10		
# 5	150	10		
	200	10		
	250	10	1500	178

Bending Test on 1/2 " OD X .049 at 45°



Gage No.	Reading(lbs)	Strain or comp.	deflection
	50	135	.0155"
	100	268	.038
	150	405	.0615
# 1	200	223	.0875
	250	150	.13
	300	90	.43
	500	94	.76
	50	532	
	100	1080	
	150	1652	
# 2	200	2020	
	250	2549	
	300	3104	
	500	6100	
	50	320	
	100	665	
	150	1010	
# 3	200	1360	
	250	1693	
	300	2028	
	500	3430	

Tensil test



GRAPHITE TESTS

1 1/2" X .050"+.006 ±5°

Weight	Deflection
0	1.551
4 lbs-6 oz.	1.560
24 lbs-6 oz.	1.604
44 lbs	1.660
64 lbs	1.717
84 lbs	1.776
104 lbs	1.810
124 lbs-6 oz.	1.858

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^3 avg.\ t}$$

$$E = 14.31 \times 10^6$$

1 1/2" X .050"-.004 ±45°

Weight	Deflection
0	1.591
4 lbs-6 oz.	1.626
24 lbs	1.862
44 lbs	2.128
64 lbs	2.370
84 lbs	2.653
104 lbs	2.964

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^3 avg\ t}$$

$$E = 2.7 \times 10^6$$

1 1/2" X .050"-.003 ± 25°

Weight	Deflection
0	1.540
4 lbs 6 oz.	1.570
24 lbs 6 oz.	1.630
44 lbs 6 oz.	1.724
64 lbs 6 oz.	1.800
84 lbs 6 oz.	1.876
104 lbs 6 oz.	1.975

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^3 avg\ t}$$

$$E = 8.52 \times 10^6$$

ALUMINUM TESTS

1 1/2" X .049"

Weight	Deflection
0	1.573
4 lbs 6 oz.	1.610
24 lbs 6 oz.	1.690
44 lbs	1.768
64 lbs	1.834
84 lbs	1.927
104 lbs	1.987

$$E = \frac{PL^3}{48\ y\ Max\ \pi\ R^3 avg\ t}$$

$$E = 8.95 \times 10^6$$

BILL B200D

TEST 16 May 84

#1

AL WT.	AL DEFLECTION	GRAPHITE WT.	GRAPHITE DEFLECTION
0 ~~0~~ lb	70 ~~3~~"	0	70"
10 ~~30~~ "	69 1/4 ~~3 1/4~~	10"	69 1/2
30 ~~50~~ #	67 3/4	30	68 1/4
50 #	66 1/4	50	67 1/4
70 #	65	70	66
90 #	63 3/4	90	65
110 #	62 1/4	110	64
130 #	61	130	63
150 #	59 3/4	150	62
160 #	59	170	61
170 #	58 1/2	~~190~~	60 1/2
180 #	57 3/4	190	60
190 #	57 1/4	200	59 1/2
200 #	56 1/2	210	59
210 #	55 3/4		
WT. of AL TUBE 9.55 #s		WT #1 TUBE	5.75 #s

#2 GRAPHIT

WT.	DR. F
0	70
10	69 1/4
30	68 1/4
50	67
70	66
90	65
110	64
130	63
150	62
170	61
180	60 1/2
190	60
200	59 1/2
210	59

WT OF #2 TUBE
5.8 lbs

FOR $D = 2\frac{1}{2}"$ SENSOR-510 CROSS-TUBE. "2" REQUIRED

$$\frac{EI}{10^6} = 34\left(\frac{\pi}{64}\right)\left(D^4 - d^4\right) \qquad \left(E_{GR.} = 34 \times 10^6 \text{ PSI}\right)$$
$$\left(E_{AL} = 10 \times 10^6 \text{ "}\right)$$

$$\left(D^4 - d^4\right)_{GR.} = K = \frac{10}{34}\left(D^4 - d^4\right)_{AL}$$

$$D^4 - d^4 = K$$
$$d^4 = D^4 - K$$

$$\frac{10}{34}D^4 - d^4_{AL} = K$$

$$(2.5)^4 - (2.402)^4 = K$$

$$39.06 - 33.67 \quad \frac{10}{34}(5.39) = 1.585 = K$$

$$d^4 = D^4 - K$$

$$K = 1.585$$

$$d^4 = (2.5)^4 - 1.584$$

$$d^4 = 39.06 - 1.584 = 37.476$$

$$d = (37.476)^4$$

$$d = 2.474"$$

O.D. GR = 2.500" OD

I.D. 2.474 ID

0.026"

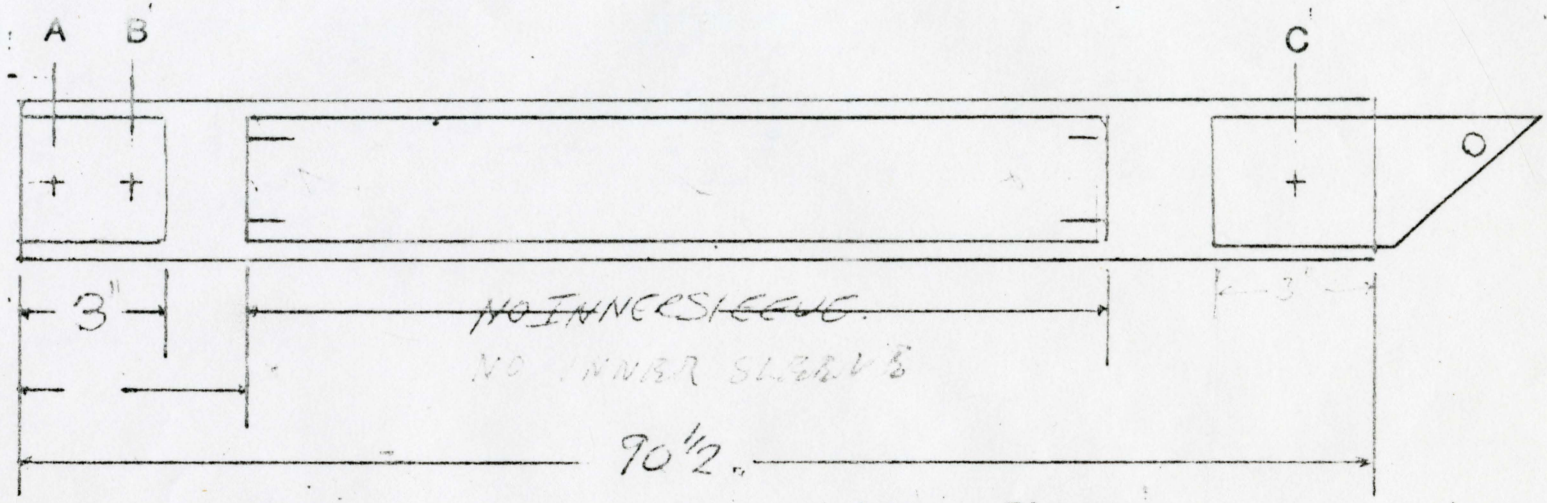
WALL THICKNESS = .013"

Folds Gone Blythe 4-14-81

1-30-81

Glider Size Comet 135 Date 4-15-81 Fm

X-Bar Material 1 7/8 x .058 ~~Innersleeve~~ ~~1 3/4 x .049~~



Hole		Size	Angle	Distance	
A	Plate At root	3/8	Top	3/4	From END of tube
B	Plate At Root	3/8	Top	2 5/8	"
C	Fitting	1/4	Top	3/4	From END of tube

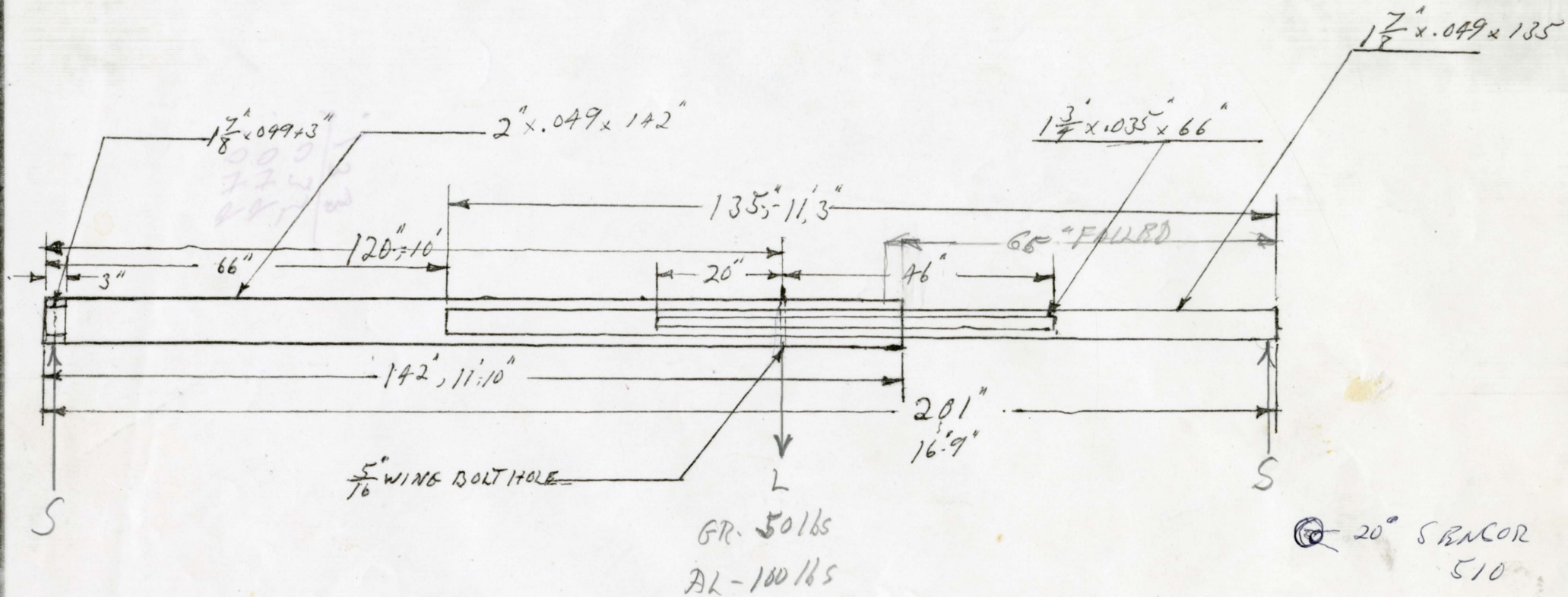
EQUIVALENT GRAPHITE SPAR

TAPERED FROM 2 1/2" OD TO 1 3/4"

(2) REQUIRED

WT. = 9.2 lbs/LE.

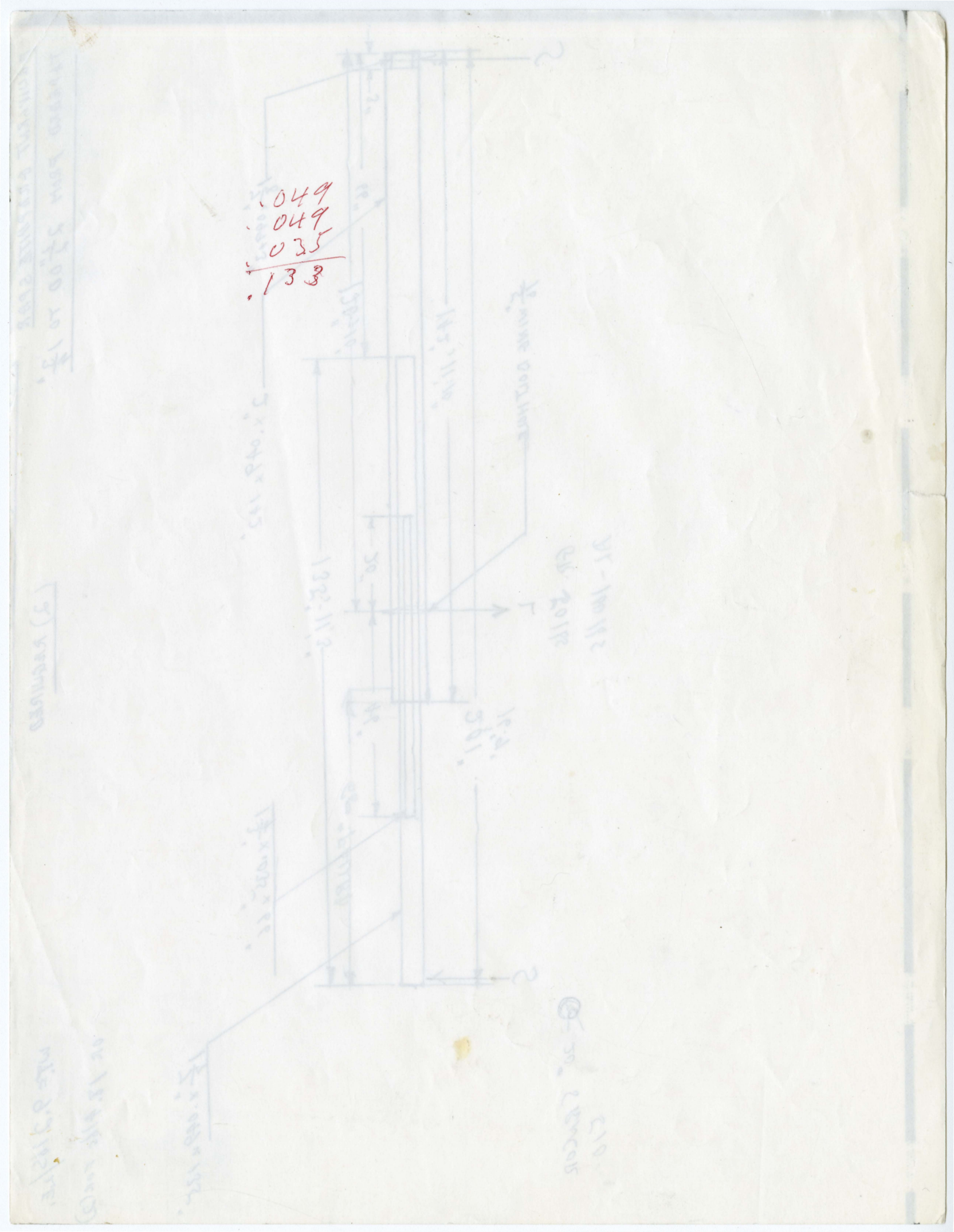
OR 18.4 lbs FOR (2)

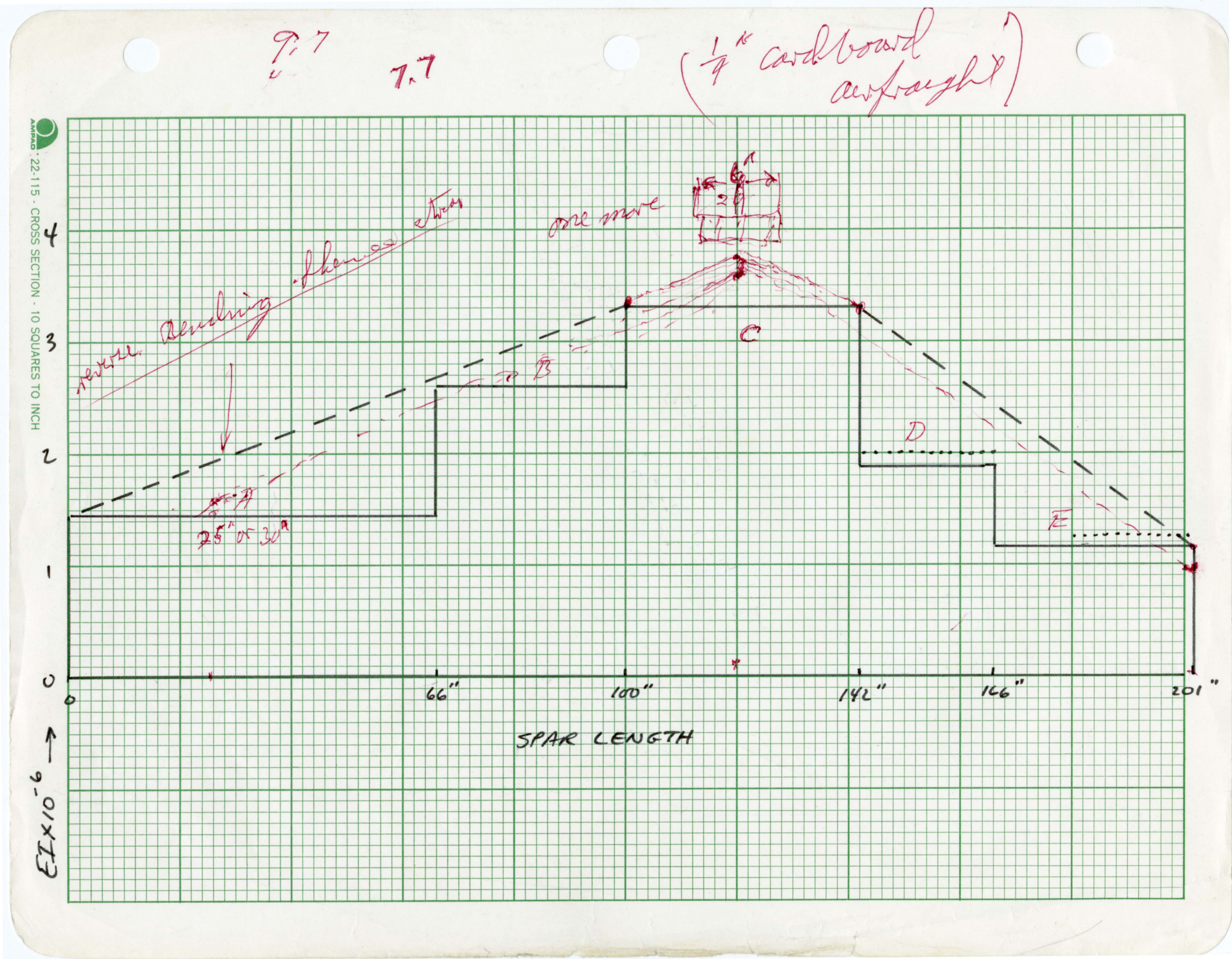


GR. 50 lbs

AL - 100 lbs

20° SRNCOR 510

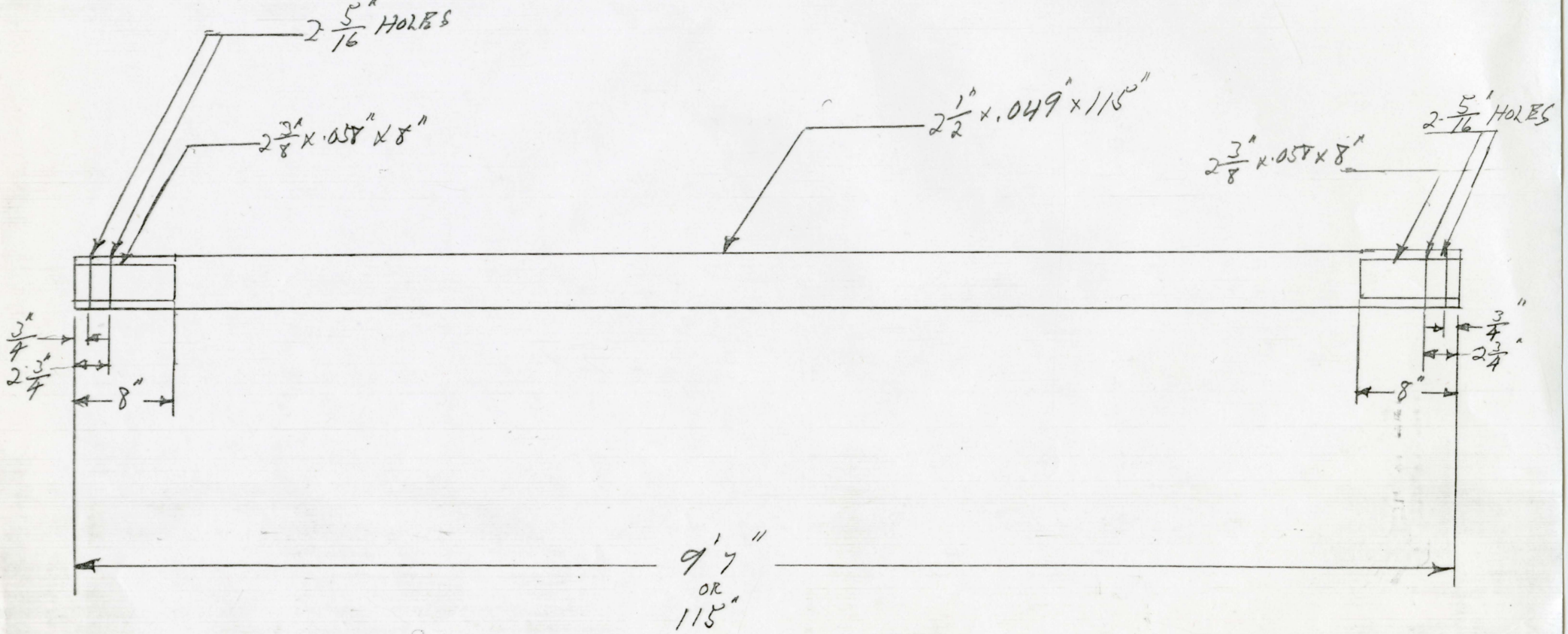

.049
.049
.035
.133


7.7
7.7
(1/4" cardboard
straight)
AMPAD 22-115 - CROSS SECTION - 10 SQUARES TO INCH
4
3
2
1
0
EI x 10^-6 →
level
Bending
flexible
one more
C
B
D
E
25° or 30°
0
66"
100"
142"
166"
201"
SPAR LENGTH

SENSOR-510-CROSSTUBE

2- REQUIRED

AL-6061-T6



GRAPHITE 2" x .050" WALL

WT.		DEF.
0	–	0
10 lbs	–	.140"
20	–	.430"
30	–	.610"
40	–	.782"
50	–	.959"
60	–	1.132
70	–	1.297
80	–	1.467
90	–	1.633
100	–	1.820

Al - 1 7/8" OD. 058" WALL

WT.		DEF
0	–	0
10 lbs	–	.195"
20"	–	.405"
30"	–	.624"
40"	=	.767"
50"	=	.910"
60"	=	1.065"
70"	=	1.230"
80"	=	1.388"
90"	=	1.546"
100"	=	1.710"

DIF. IN DEF. .110"

EQUIVALENT GRAPHITE SPAR

TAPERED FROM ~~2 1/2" OD TO 1 3/4"~~

(2) REQUIRED

ACT. WT. W/ BOLT & TIP ADD 9.7 lbs WT. = 9.2 lbs/LE.

OR 19.4 lbs FOR 2

OR 18.4 lbs FOR (2)

OD 2.1" = 3.75 lbs = 2 = 7.50 lbs - 19.4 - 7.5 = TWTS. ~~(11.9)~~ lbs

OD 1.875" = 5.75 lbs.

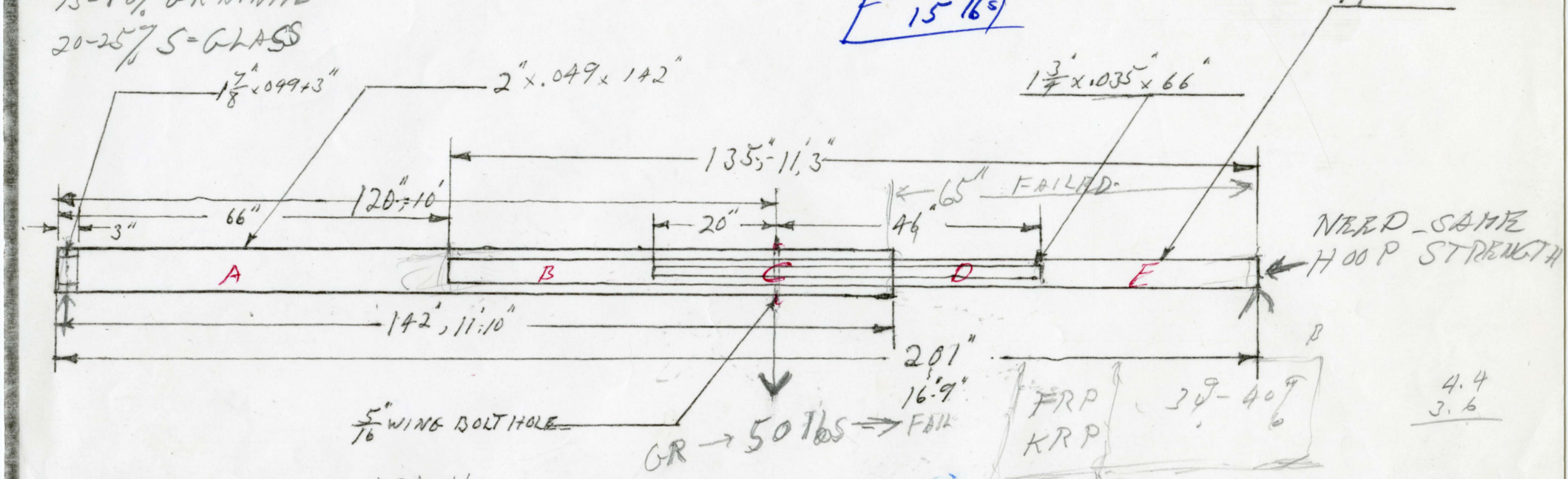
75-80% GRAPHITE

20-25% S-GLASS

TOTAL EST. WT. SAVINGS ~~25~~ lbs

~~20 lbs~~

15 lbs



KEEL AL WT. APX = 4.37 lbs

WTG. = ~~3.13~~ lbs

WS = (2.62 lbs)

AL → 100 lbs

$E_{GR.} = 34 \times 10^6$ psi

$E_{AL} = 10 \times 10^6$ psi

KING POST & DOWN TUBES TOTAL

AL WT = 1.5 lbs x 4

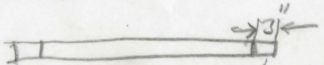
TWTA = 6.0 lbs

T&W = 2.4 lbs

WS. = (3.6) lbs

CROSS TUBE

$9\frac{1}{2}' \times 2\frac{1}{2}" \times .049"$



2=C.T. WTA = 2 1/4 x 9' = 2 x 3.57 = 7.16 lbs

WT.G. = 3.86 lbs, (WS = 3.3 lbs)

TIP

158 @ 165 - 43"

180 -46"

BATTER WT AL = 5.8 lbs

WTG. = (2.32 lbs

W.S. = (3.48) lbs

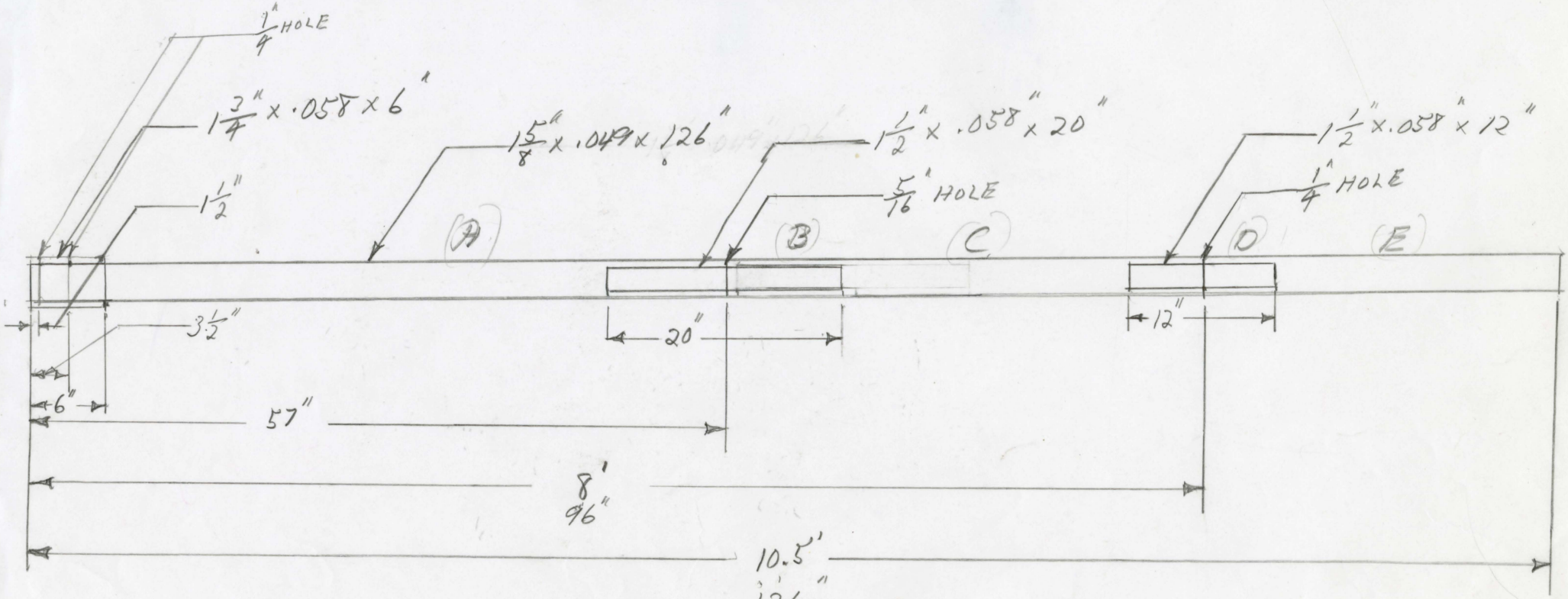
WT SENSOR 5/10 lbs

= 66 lbs

SENSOR 510 KEEL

1-REQUIRED

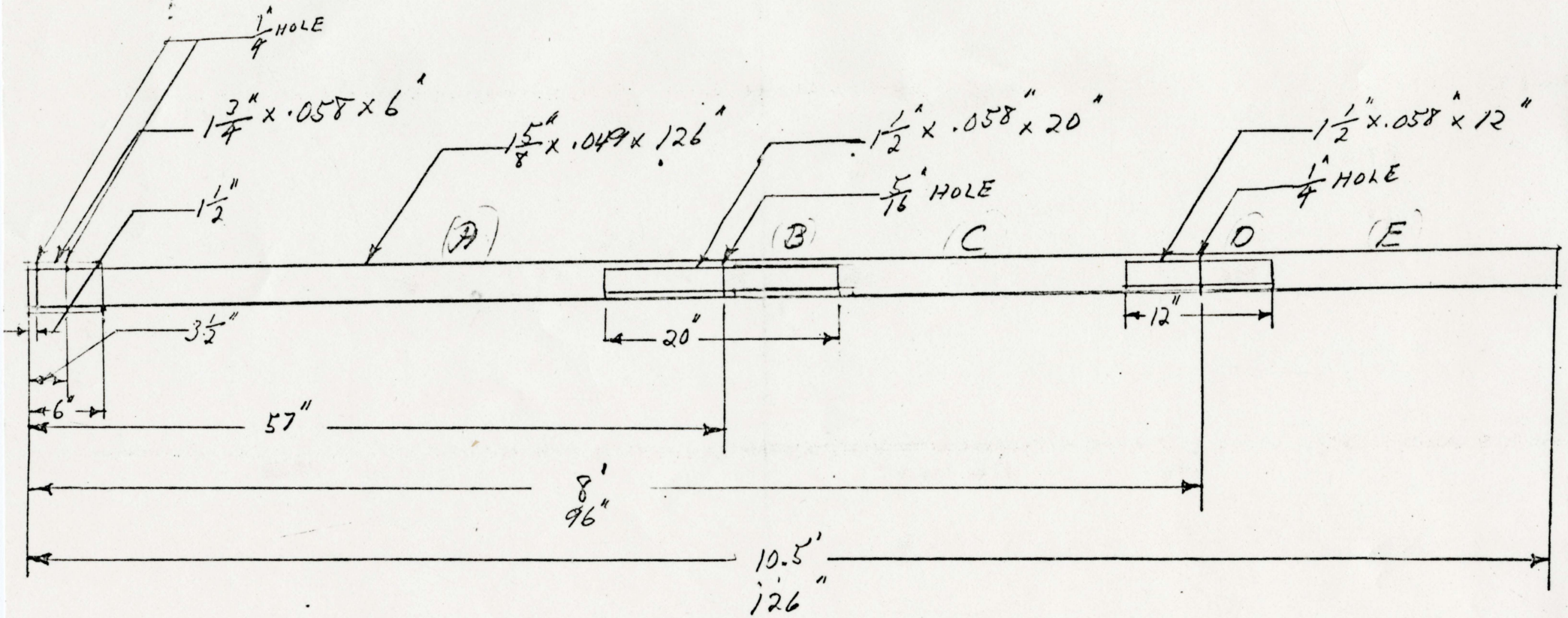
A2-6061-T6 WT/pc' = .285



WT = 3.13 lbs 1 3/4" DIA

SENSOR 510 KEEL

1-REQUIRED



SUGGEST TO REPLACE WITH EQUIVALENT GRAPHITE SPAR TAPERED FROM 2 1/2" OD TO 1 3/4"

HANG GLIDER SENSOR 510 LEADING EDGE

(2) REQUIRED

SCALE: 1/2" = 1'

WT. = 9.2 LBS/LE.

OR 18.4 LBS FOR (2)